PERIODICAL
Indo-Pac. Fish. Council
Proceedings
2nd
1950
Sections 2+3
APR 24 1951
LIBRARY
FISH & WILDLIFE SERVICE
PACIFIC OCEANIC FISHERY
INVESTIGATIONS
Sections 2+3

INDO-PACIFIC FISHERIES COUNCIL

PROCEEDINGS

2ND MEETING, 17TH—28TH APRIL, 1950

CRONULLA, N.S.W., AUSTRALIA.

SECTIONS II AND III

BANGKOK, JANUARY, 1951

INDO-PACIFIC FISHERIES COUNCIL

PROCEEDINGS

2ND MEETING, 17TH—28TH APRIL, 1950

CRONULLA, N.S.W., AUSTRALIA.

SECTIONS II AND III

BANGKOK, JANUARY, 1951

Section II

TECHNICAL PAPERS

Page

Hydrology

1. Summary to Date of the Hydrological Work of the Fisheries Division of C.S.I.R.O. - - 51

Planktology

2. Phytoplankton Studies in Eastern Australia - - - - - - - - - - - - - - - 60

Biology

3. Some Recent Advances in the Study of the Biology and Racial Divisions of the Pacific Tunas - 63

4. Bacteria in Marine Environments - 69

5. The Overfishing of the East Australian Trawl Fishery - - - - - - - - - - - 73

6. A Preliminary Report on Some Populations of the Australian "Salmon" *Arripis trutta* - 80

7. Statement of Programme - 85

Gear Technology

8. Marine Fisheries of Pakistan with a Review on Trawling - - - - - - - - - - 88

9. Report on Non-indigenous Fishing Gear. Results of the First Series of Experiments in the Operation of "Masu Ami" (a common Japanese trap net) in Thai Waters - 91

10. Indigenous Marine Fishing Gear of Thailand - - - - - - - - - - - - - - - 99

Food Technology

11. An Experiment in Fish-salting - 123

12. Fishery Products in Indo-China—a Compilation of Literature up to the Japanese Invasion 125

13. Abstracts of Other Papers Presented - - - - - - - - - - - - - - - - - - - 150

[ADENDA to this Proceedings, Section I, page 44. To the *References* to the paper by Dr. Thompson, add the following references]

BLACHE, J., (1950).—Notes et observations sur la standardisation des methodes dans les travaux sur le plankton des eaux continentals. I.P.F.C. *C50/TECH.* 35

DUSSART, B., (1949.—Les techniques de peche quantitative du plankton et le mode de representation des resultats. *Bull. Fr. de Pisiculture* Orleans, 153: 151-158.

HARVEY, H. W., (1934).—Measurement of phytoplankton population. *M. Mar. Biol. Assoc.,* N.S., 19: 761-775.

KEMP, S., & A. C. Hardy, (1929).—Discovery investigations —the ships, their equipment and the methods used in research. *Discovery Reports,* 1: 141-232.

RUSSELL, F. S., (1935).—On the value of certain plankton animals as indicators of water movements in the English Channel and North Sea. *J. Mar. Biol. Assoc.,* N.S., 20: 309-332.

SEEMAN NIELSEN, E. (1938).—Uber die Anwendung von Netzfanger bei quantitativen phytoplankton unterschungen. *J. de Conseil,* 13: 197-205.

BIBLIOGRAPHIC NOTES

The Proceedings of the Council's 1st Meeting were published in Singapore in 1950. It is tentatively suggested the abbreviation of this Proceedings should be "I.P.F.C. Proc." and since each volume has continuous pagination, it is unnecessary to give section number where the page is cited.

1

SUMMARY TO DATE OF THE HYDROLOGICAL WORK OF THE FISHERIES DIVISION, C.S.I.R.O.

by

D. J. Rochford*

ABSTRACT.

A very brief statement is given of the work carried out and of the major conclusions reached in the investigation of oceanic, neritic and estuarine waters and of estaurine mud bottoms of Australia.

DYNAMICS AND PRODUCTIVITY OF OCEANIC WATERS

The dynamics and nutrient content of waters in the eastern Australian and south-western Australian slope and offshore current systems have been investigated by F. R. V. "Warreen". In the eastern Australian area in the period 1939-1942 F. R. V. "Warreen" made two complete and one half-completed oceanographical cruises along the eastern Australian coast from latitudes 28°S-45°S. These cruises were worked during mid-summer and mid-winter oceanographical seasons. Unfortunately, due mainly to wartime conditions, 60 miles offshore was the limit of F. R. V. "Warreen's" section lines, and this proved to be insufficient to establish the hydrological features of the non-circulating Tasman Sea waters for use as a norm of reference.

The following conclusions, however, can be drawn from the eastern Australian oceanic data:—

(1) The whole of the eastern Australian area investigated is dominated by tropical—sub-tropical water masses circulated in a north-south meridional line by the eastern Australian current system.

(2) The summer-winter cycle of onshore water properties appears to be a function of the relative strength and hence offshore position of the eastern Australian system.

(3) During the winter months a persistent northward counter current movement of Bass Strait waters into the vicinity of latitude 35°S occurs. At its northern limit a clockwise eddy system with a diameter of about 30 miles is developed and governs the hydrological features of this area.

(4) During the summer months an onshore counter-current is sometimes developed between Port Stephens and Sydney and carries high temperature waters from the offshore eastern Australian current into the region north of about latitude 32°S. This movement combined with lateral intrusions discussed in conclusion (5) develops alternate pockets of high and low temperature waters in this region during the summer months.

(5) During summer months the development of vertical stratification in the shelf waters facilitates lateral intrusion of 200-300 m. water masses from the slope current into the bottom onshore region. In certain areas, notably Trial Bay at latitude 30°30′S and Port Stephens at latitude 32°40′S, this intrusion comes to the surface and upwelling occurs, which has a marked effect on mean temperature. The stations outside this upwelling area, at 31° 30′ S, 37° 20′ S, 41°20′S, and 42°30′S, have surface mean temperature lying on a straight line, the meridional decretement of which is probably a latitudinal heat loss from the same southward flowing water mass. Departures of several degrees from this normal latitudinal trend are evident in the upwelling areas.

(6) Although nutrient depletion in surface waters is common in parts of the eastern Australian area, the overall availability of nutrients appears to be fairly high in Tasmanian waters, corresponding to an average English Channel condition (Table I.).

In south-western Australia F. R. V. "Warreen" has made several oceanographical cruises in the course of her fisheries exploratory work. It has been difficult to arrange for a seasonal cover of the area under these circumstances and the only section line worked regularly has been one extending 100 miles west of Rottnest Island at latitude 32°S. From this Rottnest data the following conclusions can be drawn to date:—

(1) The current systems are relatively weakly developed and rather diffuse in their boundaries. This leads to the development of a current-stirred, upper homogeneous water mass shal-

* Hydrologist, Fisheries Divisions, C.S.I.R.O., Australia.

lower than in the eastern Australian system. The physiography of the onshore region with its offshore reefs and rather steep continental slopes does not favour lateral intrusion of the eastern Australian type.

(2) The lack of subsurface intrusion leads to a nutrient isolation of the onshore water and their general impoverishment.

(3) The lack of depth in the current-stirred layer of the oceanic waters leads to their rapid nutrient depletion during the vernal-summer plankton production peak.

(4) The diffuse and weakly developed current system leads to the development of isolated cells of high nutrient content surface waters, probably derived from an intense plankton production cycle *in situ*.

(5) There is some evidence to suggest that deeper waters in this region contain greater nutrient reserves than waters from the same latitude in eastern Australia. This is probably an effect of the shallower dynamical mixing in the former area.

(6) Surface temperatures appear to be less in the summer but greater if anything in the winter months than for waters in the same latitude on the eastern Australian coast.

PRODUCTIVITY CYCLES OF NERITIC SHELF WATERS

Since 1942, a weekly to monthly sampling of the neritic waters along the 35 fathom contour has been carried out at various stations along the eastern Australian coast. The area most persistently worked has been that between Sydney and Eden, with less information from Tasmania and only recent data from waters of northern New South Wales. Fig. 1 gives the location of the principal sampling points.

In the area between Port Stephens at latitude 32°40′S and Maria Island at latitude 42°40′S certain long-term cycles of hydrological conditions appear to be emerging.

There has been in the period 1943-1950, in the Sydney area, a persistent rise in the annual mean column content of inorganic phosphates. For the areas north and south of Sydney such data as are available display a similar trend (fig. 2). This rise in phosphates has been accompanied by a similar increase in the annual mean surface temperature, with similar or declining bottom temperature during the same period.

At the Jibbon station at latitude 34°5′S there has been a persistent and rapid rise in the mean total phosphate content of the water during the period 1942-1949 (fig. 3). The relative ratio of organic

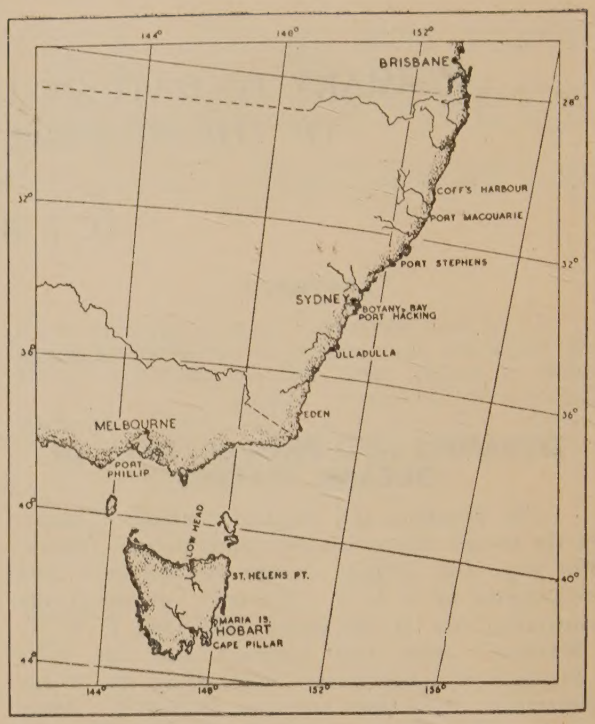


Figure 1. Map showing the location of the onshore sampling station referred to in the text.

to inorganic fractions within this total phosphate figure has varied almost inversely during the same period, and this is especially true of the bottom waters (fig. 4). It is apparent therefore that the increase in total phosphates has been brought about largely by an increase in the inorganic phosphate content of the water masses at this station.

At the entrance to Port Hacking during the same period the mean sea level has been persistently dropping (fig. 5). This mean sea level figure has been corrected for the effect of local barometric fluctuation.

The undoubted occurrence of lateral intrusions of nutrient-rich, deep offshore waters into the bottom layers at this station (fig. 6), together with the indications of persistent changes in the dynamics of the eastern Australian current system as indicated by the mean sea level variation, support a theory of abnormally persistent lateral movement as the ultimate cause of this phosphate enrichment.

In the south-western Australian coastal waters such data as are available since 1944 enable the following conclusions to be drawn:—

(1) The average content of nutrients is very low, with almost continuous summer exhaustion (table 3).

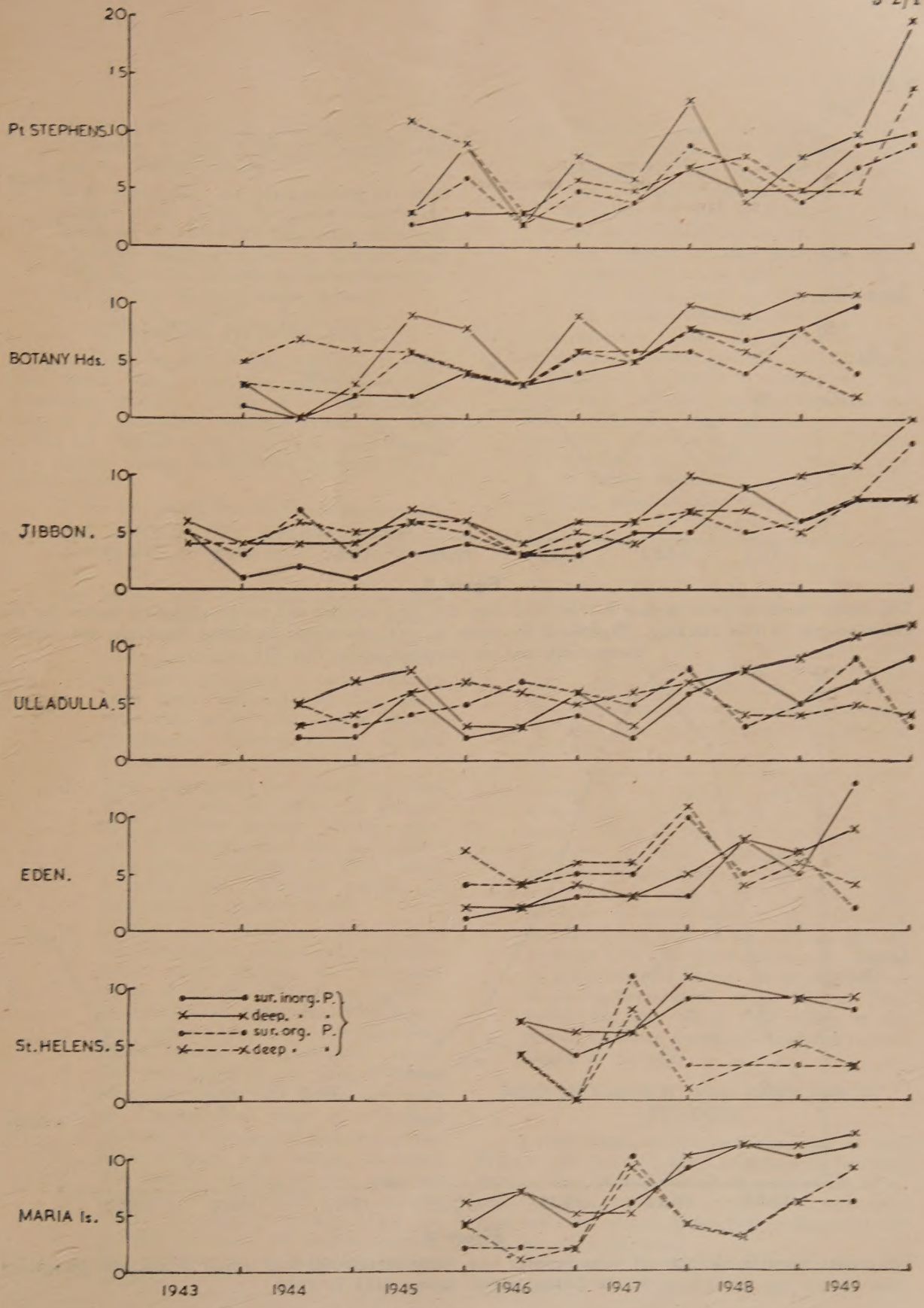


Figure 2.

The secular trends in annual mean surface (0-25m.) and mean deep (25-50m.) summer and winter column of phosphates along the eastern Australian coastline from 1943 to 1949. Phosphates are expressed as ug. PO_4 P/L.

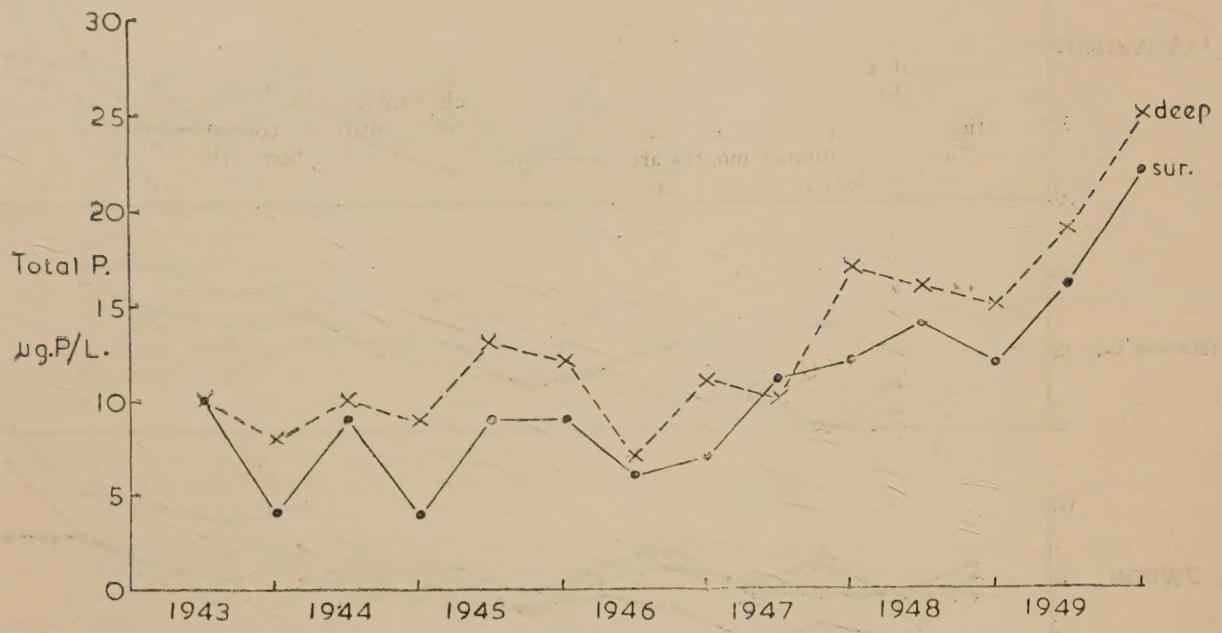


Figure 3.

The secular trend in mean surface 0-25m., and deep 25-50m., summer and winter phosphate figures for the Jibbon station off Port Hacking. Phosphates are given as total phosphates including inorganic and organic components, and are expressed as ug. PO_4 P/L

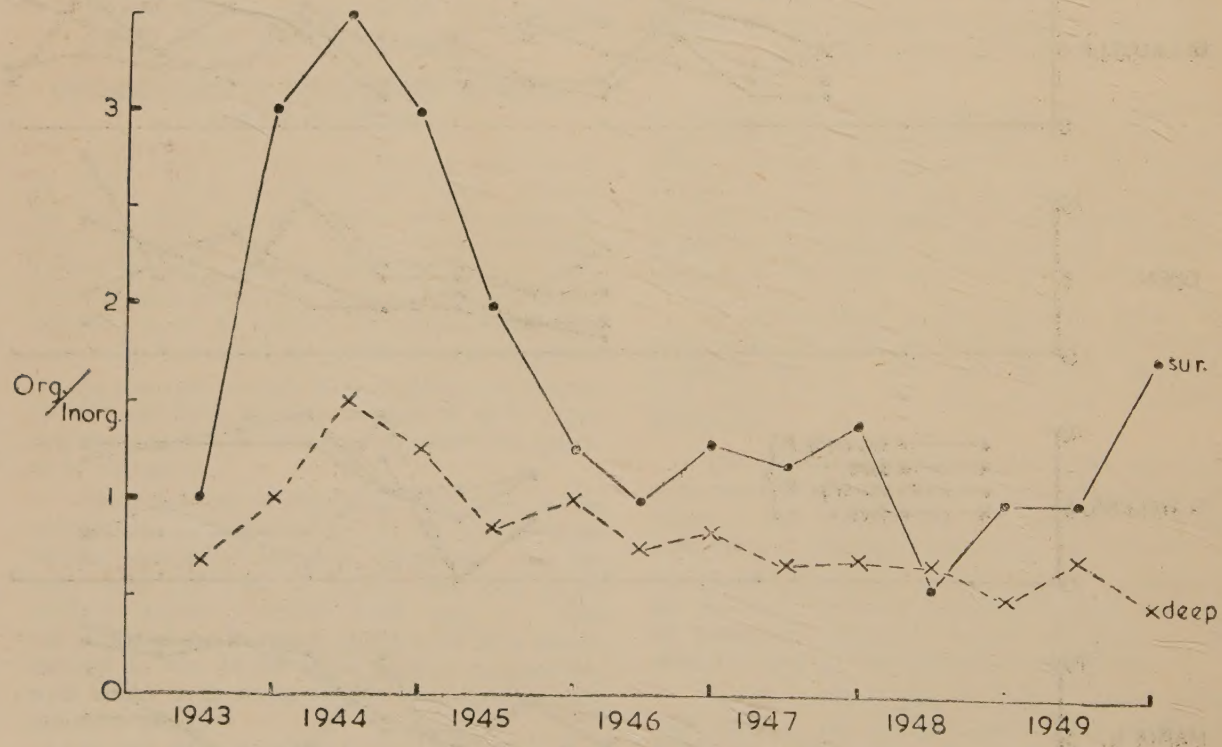


Figure 4.

The secular trends in the ratio of mean summer and winter surface and deep organic to inorganic phosphates at the Jibbon station during 1943 to 1949.

(2) No bottom reserves of nutrients are found, presumably because of the low turnover and lack of vertical stability.

(3) High chlorinities and temperatures of these onshore waters during the summer months are developed as a result of local evaporation and insolation, which processes are rendered more effective by the isolation of the onshore shelf waters from the deep oceanic waters.

ESTUARINE HYDROLOGY

Since 1940 in local waters, and later in other New South Wales, Tasmanian and south-western Australian waters, a study of the hydrological features of Australian estuarine system has been carried out. Details of this study will appear shortly in a separate paper; the following summary is presented here:—

(1) It has been found that whilst estuarine systems vary greatly in their structural features in general they are made up of the following four zones:

(a) *Marine zone*—properties similar to those of the adjoining neritic waters. Annual cycle of nutrients, with pronounced spring and autumn peaks. Bottom deposits largely composed of sand overlying black mud. Comparatively deep water with little or no tidal flats or shallow embayments. Nutrient content of bottom deposits comparatively poor.

(b) *Tidal zone*—properties resembling those of marine zone in respect of nutrient cycles. Bottom deposits, however, especially in extensive tidal flats and shallow bays, largely dominated by black, viscid flocculent mud. Nutrient content of these muds particularly high.

(c) *Gradient zone*—this zone, which occupies the transition area between tidal and freshwater zones, exhibits the maximum degree of diurnal and seasonal variation in hydrological properties. Within this zone there is a variation in chlorinity from almost marine to freshwater values. The water mass of the zone is moved back and forth by tidal forces; as a result of this oscillation there is a cyclical variation of hydrological properties at any fixed reference point within the zone. The bottom deposits of this zone are composed of grey-black low organic muds. The nutrient content is low and generally so also is the oxygen content, due probably to a persistent organic demand.

(d) *Freshwater zone*—the properties of this zone are dependent upon local soil, climatological and, in respect of temperature, altitude conditions. Its upper boundary has been arbitrarily defined as the limit of persistent annual flow. Bottom deposits of this zone are largely composed of coarse sand and larger particles up to small boulder dimensions. The nutrient content is poor.

(2) The phosphate content of the waters of such an estuarine system generally varies from a maximum in the marine to a minimum in the freshwater. In some systems rather considerable contributions of soil phosphates are found during the runoff cycle. In general, however, soil contribution of phosphates is fairly poor. In the bottom deposits the content of readily available adsorbed phosphates is found as a maximum in the tidal gradient zone. It is felt that these differing distributions of phosphates lead to or are a result of a higher degree of water productivity in marine dominated systems, and a higher degree of mud productivity in tidal-gradient zone dominated systems. The fact that marine dominated systems are excellent spatting grounds and the tidal-gradient zone systems are more suitable for adult oyster fattening is felt to be bound up with these differences in substrate productivity.

(3) The importance of tidal-generated diurnal conflicts of hydrological conditions in the ecology of estuarine systems has been ascertained. These conflicts vary from an extreme condition in which chlorinities and other properties ranging from a marine to a freshwater value are encountered in a diurnal cycle, to others in which little or no variation is encountered in spite of big tidal rise and fall of water level. In the atidal estuarine system of south-western Australia a diurnal conflict is rarely encountered except during flood cycles, and the role of tidal energy in the genesis of eastern Australian conflicts is demonstrated by analogy.

MUD METABOLIC AND ENRICHMENT STUDIES

A small laboratory has been established at Shell Point on the George's River. Some work has been done on the chemical changes in muds of the intertidal zone, and data on the hydrological, meteorological and some microplanktological conditions of this area, have been collected.

The effect of the addition of enrichment mixture on the chemical constitution and organic acti-

vity of the mud in the upper 2 feet layer of the intertidal zone has been followed over a period of years. A routine external measurement and internal examination of oysters over treated and untreated flats has been carried out during the same period. The interpretation of these growth data in respect of treated and untreated control flats has been difficult because of cross contamination of the mud substrate. In order to overcome this difficulty an enrichment experiment in an adjoining marsh with sluice gate control of the volume of water entrapped, has been commenced.

Small scale tank experiments to test the effect of various fertilizer combinations on the water and mud chemical conditions have been carried on for some time. Recently, preliminary steps have been taken to trace the course of phosphates from the mud substrate to the growing oyster by means of radio-active phosphorus.

The micro-plankton of the water has been sampled by a pumping technique, using monel metal screens to filter off the plankton. An ultracentrifuge is now available for quantitive sedimentation.

The relationships between air, water and mud temperatures during the winter months on an intertidal mud flat have been investigated by a number of fixed resistance thermometers with a portable balancing bridge circuit. The development of cold water fronts with temperatures some 5-10°C. below the average temperature of the main water mass appears to be a common feature of this zone.

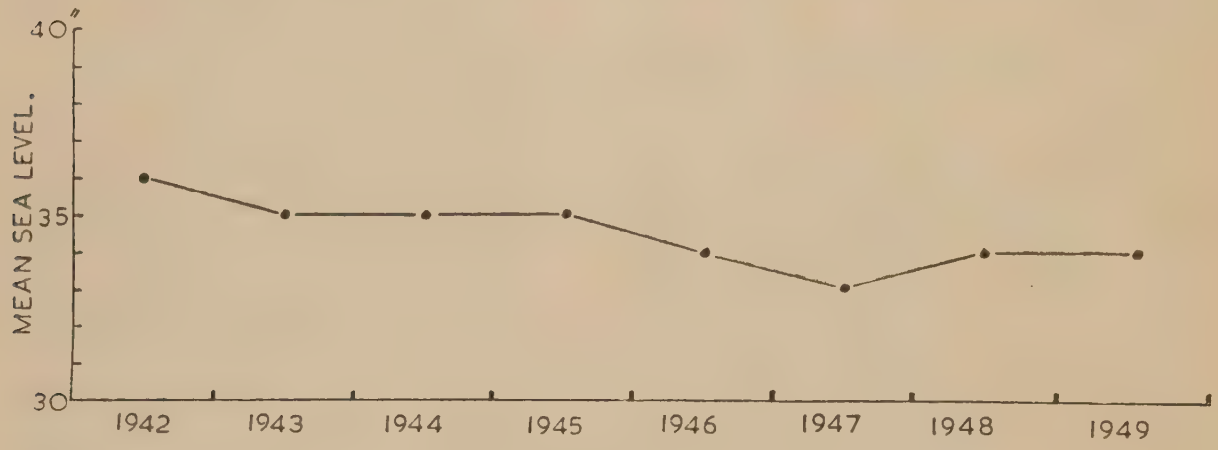


Figure 5.

The variation in annual mean sea level at the entrance to Port Hacking during 1942-1949.

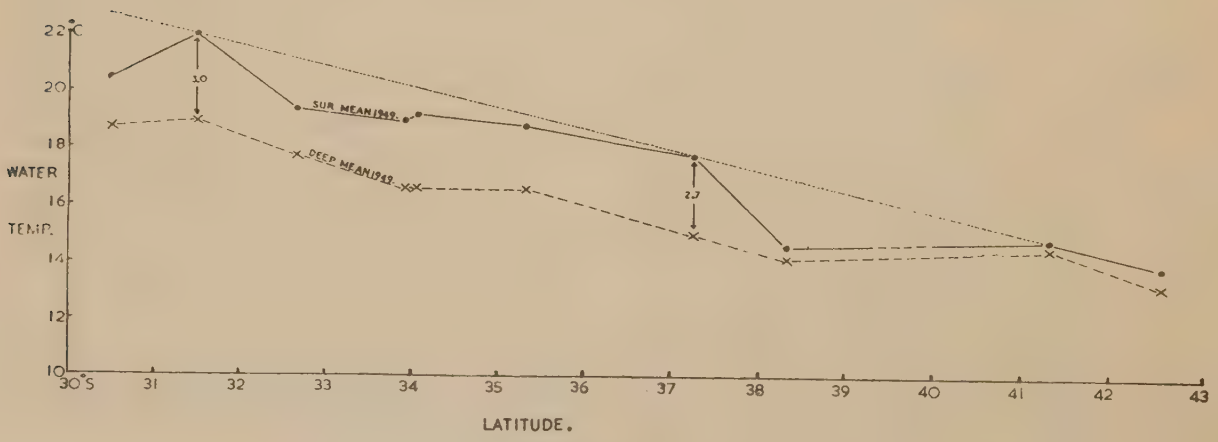


Figure 6.

The surface and 50 metre annual mean of temperature of neritic waters during 1949 along the eastern Australian coastline. The dotted line represents a normal meridional trend in the absence of upwelling.

TABLE 1.

South-eastern Australia—onshore waters—mean column phosphates expressed in ug. PO_4P/L.

Station	Year	Summer: October-April No. of Obs.	Surface Inorg. P.	Mean Org. P.	Deep Inorg. P.	Mean Org. P.	Winter: May-September No. of Obs.	Surface Inorg. P.	Mean Org. P.	Deep Inorg. P.	Mean Org. P.
Coff's Harbour	1948–49	4	6	6	15	7	4	6	8	9	4
Port Macquarie	1948–49	5	6	6	12	5	3	5	14	10	8
	1945	—					2	2	3	3	11
Port Stephens	1945–46	5	3	6	9	9	5	3	2	2	3
	1946–47	7	2	5	8	6	2	4	4	6	5
	1947–48	4	7	9	13	7	2	5	7	4	8
	1948–49	7	5	4	8	5	4	9	7	10	5
	1949	2	10	9	20	14					
Total and Grand Mean of Obs.		25	5	7	12	8	15	5	5	5	6
Botany Heads	1943–44	5	1	3	3	5	2	0	13	0	7
	1944–45	4	2	2	3	6	4	2	6	9	6
	1945–46	6	4	4	8	4	4	3	3	3	3
	1946–47	5	4	6	9	6	6	5	6	5	5
	1947–48	6	8	6	10	8(5obs.)	4	7	4	9	6
	1948–49	4	8	8	11	4	4	10	4	11	2
Total and Grand Mean of Obs.		30	5	5	8	6	24	5	6	6	5
Jibbon	1943										
	1943–44	19	1	3	4	4	13	5	5	6	4
	1944–45	16	1	3	4	5	20	2	7	4	6
	1945–46	9	4	5	6	6	10	3	6	7	6
	1946–47	11	3	4	6	5	7	3	3	4	3
	1947–48	7	5	7	10	7	8	5	6	6	4
	1948–49	8	6	6	10	5	6	9	5	9	7
	1949	5	8	14	17	8	7	8	8	11	8
Total and Grand Mean of Obs.		75	4	6	8	6	71	5	6	7	5
Ulladulla	1944										
	1944–45	5	2	3	7	4	4	2	5	5	3
	1945–46	7	2	5	3	7	4	6	4	8	6
	1946–47	7	4	6	6	5	4	3	7	3	6
	1947–48	4	6	8	7	7	5	2	5	3	6
	1948–49	7	5	5	9	4	3	8	3	8	4
	1949	3	9	3	12	4	3	7	9	11	5
Total and Grand Mean of Obs.		33	5	5	7	5	23	5	6	6	5
Eden	1945–46	5	1	4	2	7	4	2	4	2	4
	1946–47	6	3	5	4	6	5	3	5	3	6
	1947–48	4	3	10	5	11	4	8	5	8	4
	1948–49	6	5	7	7	6	2	13	2	9	4
Total and Grand Mean of Obs.		21	3	7	5	8	15	7	4	6	5
Port Phillip	1948–49	2	5	7	6	6	3	10	4	7	4
St. Helens	1946						2	7	4	7	4
	1946–47	1	4	0	6	0	2	6	11	6	8
	1947–48	2	9	3	11	1	—	—	—	—	—
	1948–49	4	9	3	9	5	1	8	3	9	3
Total and Grand Mean of Obs.		7	7	2	9	2	5	7	6	7	5
Maria Island	1945–46	1	4	2	5	4	4	7	2	7	1
	1946–47	5	4	2	5	2	5	6	10	5	9
	1947–48	4	9	4	10	4	3	11	3	11	3
	1948–49	4	10	6	11	6	1	11	6	12	9
Total and Grand Mean of Obs.		14	7	4	8	4	13	9	5	9	6
Cape Pillar	1948–49	4	10	3	9	4	1	13	1	14	1

TABLE 2.

South-eastern Australia—onshore waters—temperatures °C.

Station	Surface: 0 m. Year	No. of Obs.	Max.	Mean	Min.	Range	Deep: 50 m. Year	No. of Obs.	Max.	Mean	Min.	Range
Coff's Harbour	1949	8	22.60	20.43	18.50	4.10°	1949	8	22.60	18.71	14.62	7.98°
Port Macquarie	1949	7	25.00	21.91	19.15	5.85°	1949	7	21.51	18.94	18.10	3.41°
Port Stephens	1946	12	22.40	18.40	15.40	7.00°	1946	12	19.80	16.42	14.10	5.70°
	1947	9	22.50	19.72	16.00	6.50°	1947	9	20.20	16.75	14.80	5.40°
	1948	9	22.40	19.44	15.10	7.30°	1948	9	19.80	17.36	15.20	4.60°
	1949	9	21.30	19.26	16.50	4.8°	1949	9	19.95	17.68	15.30	4.65°
Total and Grand Mean of Obs.		39	22.15	19.22	15.75	6.40°		39	19.94	17.05	14.85	5.09°
Botany Heads	1943	4	19.75	17.71	15.30	4.45°	1943	4	17.50	16.23	14.30	3.20°
	1944	8	22.40	18.94	16.40	6.00°	1944	8	20.50	17.17	13.50	7.00°
	1945	12	21.30	17.91	15.30°	6.00°	1945	12	19.15	16.17	13.90°	5.25°
	1946	9	20.70	18.08	15.00°	5.70°	1946	9	19.60	16.70	14.60°	5.00°
	1947	11	21.10	18.15	16.00	5.10°	1947	11	19.90	16.62	13.60	6.30°
	1948	10	21.60	17.79	15.00	6.60°	1948	10	20.60	16.75	14.60	6.00°
	1949	7	23.40	18.86	14.00	9.40°	1949	7	19.20	16.51	14.00	5.20°
Total and Grand Mean of Obs.		61	21.46	18.21	15.29	6.18°		61	19.49	16.59	14.07	5.42°
Jibbon	1943	28	22.00	17.66	13.70	8.30°	1943	28	20.45	16.15	14.00	6.45°
	1944	37	23.75	18.52	15.30	8.45°	1944	37	21.12	16.55	14.10	7.02°
	1945	22	21.72	19.10	15.95	5.77°	1945	22	19.80	16.83	13.20	6.60°
	1946	21	23.00	18.49	15.20	7.80°	1946	21	20.05	16.31	13.60	6.45°
	1947	16	21.60	18.43	16.00	5.60°	1947	16	19.60	16.06	13.20	6.40°
	1948	16	22.80	18.16	14.00	8.80°	1948	16	20.60	16.56	13.30	7.30°
	1949	15	24.50	19.02	16.80	7.70°	1949	15	19.20	16.48	13.00	6.20°
Total and Grand Mean of Obs.		155	22.77	18.48	15.28	7.49°		155	20.12	16.42	13.49	6.63°
Ulladulla	1944	7	17.30	15.82	14.30	3.00°	1944	7	15.30	13.93	12.21	3.09°
	1945	11	19.92	17.47	14.90	5.02°	1945	11	19.87	16.07	13.90	5.97°
	1946	10	21.00	16.95	12.50	8.50°	1946	10	19.10	15.66	12.25	6.85°
	1947	10	19.95	16.87	13.00	6.95°	1947	10	18.20	15.46	12.80	5.40°
	1948	9	22.00	17.43	14.38	7.62°	1948	9	19.65	16.11	13.05	6.60°
	1949	10	22.00	18.65	14.95	7.05°	1949	10	19.50	16.48	13.50	6.00°
Total and Grand Mean of Obs.		57	20.36	17.20	14.00	6.36°		57	18.60	15.62	12.95	5.65°
Eden	1946	11	19.60	16.06	11.80	7.80°	1946	11	19.10	15.13	11.50	7.60°
	1947	11	20.10	15.95	12.20	7.90°	1947	11	17.00	14.51	12.20	4.80°
	1948	10	19.50	15.12	11.40	8.10°	1948	10	18.55	14.37	11.00	7.55°
	1949	7	21.00	17.55	13.40	7.60°	1949	7	17.30	14.90	11.50	5.80°
Total and Grand Mean of Obs.		39	20.05	16.17	12.20	7.85°		39	17.99	14.73	11.55	6.44°
Port Phillip	1949	9	17.95	14.54	11.70	6.25°	1949	9	16.55	14.06	11.75	4.80°
St. Helens	1949	4	16.01	14.77	13.78	2.23°	1949	4	15.89	14.42	13.57	2.22°
Maria Island	1946	10	15.37	12.50	10.30	5.07°	1946	10	15.13	12.17	10.00	5.13°
	1947	9	16.75	13.57	11.45	5.30°	1947	9	15.25	13.05	11.40	3.85°
	1948	9	15.80	12.95	11.05	4.75°	1948	9	14.50	12.34	10.57	3.93°
	1949	5	15.49	13.80	11.58	3.91°	1949	5	15.30	13.19	11.49	3.81°
Total and Grand Mean of Obs.		33	15.85	13.21	11.10	4.76°		33	15.05	12.69	10.87	4.18°
Cape Pillar	1949	4	13.82	13.53	13.00	0.82°	1949	4	13.68	13.12	12.39	1.29°

TABLE 3.

South-western Australian—onshore—waters—mean column phosphates expressed as /ug. PO_4 P/L.

Station	Year	Summer: October-April No. of Obs.	Surface Inorg. P.	Deep Inorg. P.	Winter: May-September No. of Obs.	Surface Inorg. P.	Deep Inorg. P.
Abrolhos Section	1943–44	1	3	3			
	1944–45	1	0	0			
	1945–46				1	6	7
	1946–47	1	0	0	1	0	0
	1947–48	2	1	2	1	3	–
	1948–49	1	2	0	1	7	8
Total and Grand Mean of Obs.		6	1	1	4	4	5
Rottnest	1946–47	1	3	2	1	3	–
	1947–48	2	2	2	1	0	0
	1948–49	5	3	2	2	2	3
Total and Grand Mean of Obs.		8	3	2	4	2	2
Albany	1946–48	2	2	3	2	1	0
	1947–48	1	10	10	2	2	3
	1948–49	1	1	0	2	5	–
Total and Grand Mean of Obs.		4	4	4	6	3	3

2

PHYTOPLANKTON STUDIES IN EASTERN AUSTRALIA

by

E. J. Ferguson Wood*

ABSTRACT.

Phytoplankton studies on material collected by the research vessels of the Division of Fisheries of C.S.I.R.O. show that indicator species are present which may be used for observing tropical, sub-tropical, sub-antarctic and estuarine influences. From this, movement of currents, mixing of water, etc., may be observed, although the data are too meagre for any detailed discussion on the annual movement of water masses. Enough preliminary work has been done to allow of such discussion of and when the necessary phytoplankton catches are made.

Important forms are tropical—*Ornithocercus, Histioneis, Ceratocorys, Chaetoceros coarctatus, Rhizosolenia latissima,* etc.; neritic—*Dinophysis caudata, D. tripos, D. schroederi, Ceratium trichoceros, Gondiodoma polyedricum,* etc.; sub-antarctic—*Rhizosolenia hebetata, Chaetoceros criophilium, Ceratium intermedium.*

Phytoplankton studies can be important for two reasons:—

1. All animal life is, in the first instance, dependent on plants assembling inorganic materials in organic form. Thus, productivity in the sea depends on phytoplankton, since non-planktonic algae are confined to the coastline and are rarely used as food by marine animals.

2. Certain indicator species can be readily detected in phytoplankton and these can be used to show whether a sample of seawater is derived from tropical, sub-tropical and arctic or sub-antarctic regions, or whether it is a mixture of some of these. There are limitations as to the depth at which phytoplankton grows, but, when we are dealing with surface waters, valuable information can be rapidly obtained.

In a study of phytoplankton as food, i.e., productivity, quantitative methods are necessary. This requires almost continuous sampling and the measurement of volumes sampled. Unfortunately, plankton is not uniformly distributed in the sea and duplicate samples may give very different quantitative estimates. In Britain there are two schools of thought regarding the best method of estimating plankton, one considering that a measuring net is the best means available, and the other favouring theoretical. In either case, productivity can be pumps. Both have serious drawbacks, practical and determined only from a large number of samples, and in addition, a great deal must be known about the area studied, so that the samples may be representative, e.g., stations must be selected so that they will not be unduly influenced by local conditions (river floods, etc.) As a further instance, it is desirable to choose stations in the neighbourhood of a convergence rather than a series of stations in a uniform body of water.

As our facilities do not enable us to take samples from far offshore or to cover the coastline of Australia at all adequately, we have not undertaken productivity studies apart from purely local studies in estuaries. Even these estuarine studies require a great deal of work to correlate them with fish production and hydrological data.

We have used both pump and net collection though, so far, have not used nets with meters. We do intend, when conditions are more favourable as regards staff and vessels, to make our hauls as quantitative as possible, so that raw data, however meagre, may be available to future workers.

We have, therefore, been forced to confine our attention to the second function of phytoplankton investigation which is qualitative and roughly quantitative. This gives us seasonal fluctuations, maxima and minima of species and an idea of their significance without giving any information on productivity.

At our disposal at Cronulla are plankton samples, taken between 1939 and 1950 from Port Hacking, with some gaps during the war period, a collection from cruises by F. R. V. "Warreen" from southern Tasmania to Queensland between 1938 and 1940, and a little material from Moreton Bay, Queensland, Northern Australia and New Guinea. Unfortunately, there are few fine mesh net samples, so that the phytoplankton record has serious gaps. Unfortunately not all the New Guinea plankton, and none of the Heard Island plankton have yet arrived at Cronulla, so this paper can only be an interim report.

The data available even on a rapid analysis are capable of giving some useful results.

DISTRIBUTION OF SPECIES

1. *Dinoflagellates.* Among the dinoflagellates, *Dinophysis* may be regarded as estuarine and neritic.

* Bacteriologist, Division of Fisheries, C.S.I.R.O., Australia.

A more northerly form, characteristic of Moreton Bay to Port Hacking is *D. caudata*, while *D. tripos* occurs as far south as Tasmania. It overlaps *D. caudata* somewhat, being more prevalent at Port Hacking, less so in Middle Harbour. Both forms are found in the "Warreen" plankton. *D. schroederi* is frequent in Port Hacking and Sydney Harbour and transition forms between the three species are so common that I feel that they may all be varieties of the same species. Kofoid (1928) puts *D. tripos* (= *D. homunculus* of Paulsen) with *D. caudata*. *D. okamurai* is a Port Hacking form and *D. norvegica*, *D. hastata*, etc., are sub-tropical and probably neritic, extending into the estuaries. *D. miles* has only been found in plankton from Lae, New Guinea, and is listed by Karsten (1905) as a tropical form. It seems to be neritic.

Phalacroma hindmarchi is a southern form, while *P. argus*, *P. doryphorum*, *P. rapa*, *P. ovum* and *P. mitra* seem to be northern forms.

Amphisolenia and *Triposolenia* have not been found. *A. globifera* has been recorded by Hart (1934) from "Discovery" plankton as a tropical form.

Goniodoma polyedricum is a tropical form, occurring from New Guinea to latitude 39°S. and is recorded from tropical waters by Hart.

Pyrophacus horologicum, regarded by Lebour as widely distributed, is regarded by Hart and myself as tropical. So also is *Podolampas bipes* which also occurs in Port Hacking.

Noctiluca scintillans is sub-tropical, *Gymnodinium* (*Pyrocystis*) *lunula* occurs as far south as 44°S, though Hart regards it as tropical and sub-tropical. *G. robusta* and *G. semicircularis* have not been found south of latitude 30°S.

Histioneis (*H. hippoporoides*) has been found only once—off Montague Island. Kofoid regards it as essentially oceanic tropical, so its occurrence south of Sydney must be due to the presence of tropical waters.

Ornithocercus spp. have been found as far south as 43°S and, since all authors consider this genus as oceanic tropical-sub-tropical, they must indicate the presence of oceanic northern influence.

Hart considers *Gonyaulax polygramma* as a sub-antarctic indicator, but this species has been identified as far north as Moreton Bay. Since it is difficult to identify, it seems necessary to check my own identification.

Diplopsalis has not been found south of Port Hacking, but as this is an estaurine form, this may be due to the paucity of estuarine samples from the more southerly stations.

Ceratocorys horridum is regarded by Karsten and myself as tropical, but has been found with other tropical forms to extend to latitude 43°S on one occasion (August 1940). The naked forms except for the Pyrocystis group are estuarine and so are *Prorocentrum*, *Exuviaella* and *Protoceratium*. *Oxytoxum* has been rare in these samples.

Peridinium is a very widely spread genus, often neritic and estuarine. Gran considers *P. pellucidum*, *P. ovatum*, *P. decipiens*, *P. steinii*, *P. pentagonum* and *P. depressum* to be boreal-oceanic, and Hart regards *P. oceanicum* and *P. globulus* as tropical. I have found all these species except *P. globulus* abundant in Port Hacking, so they must be regarded as neritic or as cosmopolitan. The same applies to *P. cerasus*, *P. roseus*, *P. claudicans* and *P. orbiculare*.

Australia differs from Europe in that *Ceratium* is more frequently estuarine here than elsewhere. Lebour (1925) cites *C. hirundinella* as the only common fresh to brackish water species. This species is rarely found in Australian waters, but *C. furca*, *C. fusus*, *C. pennatum*, *C. extensum*, *C. macroceros*, *C. candelabrum* (tropical according to Hart) and *C. tripos* occur often in brackish water and are common in estuaries. *C. trichoceros* is a common form in New Guinea and tropical and sub-tropical Australian waters. It is found in Port Hacking, suggesting tropical oceanic influence in this estuary, especially as it is associated with the oceanic diatom *Planktoniella sol* which is frequent in Port Hacking. *Ceratium batavum*, *C. gravidum*, *C. teres* and *C. bucephalum* are tropical oceanic forms.

2. *Diatoms.* Among the diatoms *Chaetoceros criophilum* and *Rhizosolenia hebetata* occur in Tasmanian waters and have not been found north of Twofold Bay. They are associated with *Ceratium intermedium*, confirming the southern origin of the water. Hart (1934) considers *Ch. criophilum* to be restricted to antarctic and sub-antarctic waters and Ostenfeld (1931) records *Rhizosolenia hebetata* as an arctic-oceanic type, though Hart does not record it.

Tropical forms occurring from New Guinea to Montague Island, and occasionally farther south are *Climacodium frauenfeldianum*, *Lauderia annulata*, *Rhizosolenia bergoni*, *R. latissima*, *Chaetoceros peruvianus*, *Hemiaulus haucki* and *Ch. coarctatum*. These have the same range as the dinoflagellates *Ceratocorys horridum*, *Gonyaulax pacifica*, *Ornithocercus magnificus*, *O. quadratus*, *Dinophysis schroederi*, etc. *Stephanopyxis palmeriana*, *S. turris*, *Streptotheca thamensis*, *Schroederella delicatula*, *Rhizosolenia calcar-avis*, etc., occur from New Guinea to Twofold Bay, and in certain seasons (notably August, 1940) south of this, as do *Ornithocerus thurni*,

Dinophysis caudata, D. tripos, etc., among the dinoflagellates.

It will be realised from this that we can distinguish sub-antarctic water, tropical oceanic water and neritic influence by the phytoplankton.

In these collections, as in those of "Discovery" recorded by Hart and Hardy, the diatoms are the most important part of the phytoplankton from a productivity standpoint, although in New Guinea waters the blue-greens *Oscillatoria, Lyngbya* and *Trichodesmium* outnumber the diatoms in many of the samples. Among the blue-greens the parasitic *Richelia* is usually found on species of *Rhizosolenia* from tropical waters.

SOME RELATIONSHIPS BETWEEN OCEANIC AND ESTUARINE FLORAS

One important feature of Australian phytoplankton is the occurrence in certain estuaries of forms usually regarded as oceanic. In Port Hacking, for example, *Ornithocercus magnificus* and *O. quadratus* have been found on two occasions. These are probably due to the influx of oceanic water from the east Australian current, but the common occurrence of such species as *Ceratium trichoceros* and *Chaetoceros coarctatum* suggests a more permanent state. This is confirmed by the frequent occurrence and apparent multiplication in Gunnamatta Bay of *Planktoniella sol* (generally regarded as truly oceanic), *Stephanopyxis, Schroederella delicatula, Streptotheca, Rhizosolenia robusta* and *Chaetoceros* species. These estuaries are drowned valleys with a deep floor (up to 90 metres) and a shallow entrance (12 metres or less). I consider that there is therefore stratification within the euphotic zone, so that the phytoplankton in the lower layer is constant in its oceanic neritic character while the upper tidal layer has a neritic flora with estuarine elements, mixing occurring between lower and upper layers in sunny weather. The presence of non-estuarine forms is too frequent and too profuse—often more so than outside—for these forms to be continually brought in with the tide. Unless they were able to escape freshets they would be killed off and replaced by an estuarine flora which does predominate at times, e.g., the almost pure Gonyaulax flora of Middle Harbour at the present time.*

RELATIONS BETWEEN ESTUARINE PHYTOPLANKTON AND THE FLORA OF ESTUARINE MUDS

A curious feature of the plankton in the tidal water flowing over the mud flats in Botany Bay and Port Hacking is that it is largely neritic in character, while the mud flora consist largely of sessile forms. There is little exchange between the two. The muds contain pennate diatoms with some *Coscinodiscus* species while these forms (except for the ubiquitous *Nitzschia seriata, N. closterium, Climacosphenia* and a few other forms) are rare in the water. Yet glass plates suspended in the water at various depths become covered with pennate diatoms in a few days at certain times of the year. It would seem that the sessile pennate forms are stimulated to rapid reproduction by the presence of a surface possibly related to the adsorption of nutrient salts on the surface. There is confirmation of this in some laboratory experiments carried out at Cronulla.

SEASONAL FLUCTUATIONS

There appear to be two main diatom maxima along the whole east coast of Australia, one in September-October and the other in May-June, with a minor peak in January-February. There are dinoflagellate peaks in late December-January, sometimes January-February and October-early November. The peaks of estuarine forms, e.g., *Gonyaulax spinifera* appear to coincide with those of the neritic and oceanic forms. At times the peaks consist of one species, e.g., *Ceratium furca, C. fusus, Rhizosolenia robusta,* but more frequently a number of species of the same genus are involved, e.g., *Ceratium tripos-macroceros-trichoceros-ostenfeldi,* and *Chaetoceros* spp. Sometimes several genera, e.g. *Skeletonema, Stephanopyxis, Planktoniella, Ditylum,* etc., may be involved. Often too, there is a series of peaks rather than a single maximum owing to consecutive peaks of different forms.

At times, one finds pure or almost pure phytoplankton in the hauls followed a week or so later by hauls with no phytoplankton. Has this been grazed off completely by the zooplankton; if so, what does the zooplankton feed on? It must either be completely carnivorous or else be able to live for some time without grazing. This phenomenon adds difficulty to productivity studies on a coastline such as this where such changes from phytoplankton to zooplankton to mixed hauls and back again seem both frequent and sudden.

PHYTOPLANKTON AS AN INDICATOR OF WATER MOVEMENTS

We have reached some interesting conclusions regarding water movements off the east Australian coast from evidence provided by the phytoplankton. It would appear that, broadly speaking, the tropical and sub-tropical forms occur along the New South Wales coast from December to February. At times, in the winter and spring, the tropical water lies

* April, 1950.

farther off the coast, its place being taken by water containing a mixture of forms including estuarine and neritic species. The tropical water may turn back to the coast near Montague Island or even further south, and strong tropical influence may reach the east coast of Tasmania as in August 1940, when a number of tropical diatoms and dinoflagellattes were collected there by F.R.V. "Warreen". Southern, sub-antarctic forms are found at times as far north as Twofold Bay. These water movements are discussed in greater detail in a paper now in press.

Enough has been said to show that regular hauls for phytoplankton on the east Australian coast can give very useful information regarding water movements. We now know the indicator species, and once we know the relation between water movements and pelagic fish occurrences we should be able to predict the movement of these fish from regular phytoplankton hauls. Unfortunately, up to the present we have had too many gaps in the plankton record to allow of our plotting water movements or relating the seasons with phytoplankton occurrences. It is, perhaps, not easy to justify such an intensive plankton programme without a large pelagic fishery. At the same time, such a programme could help to economise effort in the actual fishery as soon as water movements could be interpreted in terms of fish production.

REFERENCES

HARDY, A. C. and Gunther, E. R. (1935).—Plankton of the South Georgia whaling grounds and adjacent waters, 1926-7. Discovery Reports 11: 1-456.

HART, T. J. (1934).—On the phytoplankton of the south-west Atlantic and the Bellingshausen Sea. Discovery Reports 8: 3-220.

KARSTEN, W. (1905).—Wiss. Ergebnisse der Deutsch Tiefsee Exped. Valdivia II(2).

KOFOID, C. A. and Skagsberb, T. (1928).—The dinoflagellata; the dinophysidae. Mem. Mus. Comp. Zool. Harvard. 51: 1928.

LEBOUR, M. V. (1925).—The dinoflageliates of northern seas. Mar. Biol. Ass. U. K.

OSTENFELD, C. H. (1931).—Concluding remarks on the plankton collected on the quarterly cruises in the years 1902-1908. Cons. Internat. Bull.

3

SOME RECENT ADVANCES IN THE STUDY OF THE BIOLOGY AND RACIAL DIVISION OF PACIFIC TUNAS

by

Milner B. Schaefer*

ABSTRACT

Valuable results are being obtained from research into those factors of the life history of the tunas which are of basic importance to the development and management of the fisheries for them. Methods of racial study by means of morphometric measurements have been developed and are being applied to data from several areas in the Pacific. The growth of yellowfin tuna and skipjack is being studied by means of size frequency measurements, and the results indicate conclusively that these species are rapidly growing and that the commercial stocks consist at any time of only a small number of year classes. This has important implications regarding possible effects on stability of yields under heavy exploitation. Spawning grounds of several tuna species have been located in various places in the Pacific, and it is likely that the several species all spawn pretty generally throughout much of their ranges. Studies are going forward to determine the variation of quantity of spawning in space and time, a knowledge of which is important to judging possible fluctuations in recruitment to the commercial stocks.

Scientific investigation of the life history and ecology of commercially valuable fish species has the pragmatic objective of furnishing a factual basis upon which man may obtain the greatest production of food from the fishery for members of the species. Knowledge of facts concerning the biology of a fish species is valuable in this respect in two ways. First, by attaining an understanding of the behavior of the fish, particularly as related to seasonal and environmental changes, means may be devised for their more efficient capture and so increase the production of the fishery. This we seek to do in developing a fishery for little exploited species. As a fishery becomes more effective, however, we eventually reach a condition when increasing fishing intensity may result in actually decreasing the production, give rise to large fluctuations in the catch, or otherwise produce undesirable results. The second useful purpose of biological research is to assemble the facts regarding those fundamental factors in the life history and behavior of the fish which will enable us to understand, and indeed to predict with some assurance, the effects of changing effectiveness of fishing; to reach an understanding

* Aquatic Biologist, Pacific Oceanic Fishery Investigation, U.S. Fish & Wildlife Service, Honolulu

of what is often termed the "population dynamics" of the species.

Both in the Atlantic and Pacific, the tunas have been the objects of commercial fishing from the earliest times and, likewise, they have attracted the attention of marine biologists for hundreds of years. Due to their large size and their pelagic, oceanic habitat, however, knowledge of their ways of life is very meagre, even in view of the hundreds of papers which have been written concerning them. Except perhaps for the research conducted in certain parts of the Mediterranean Sea and adjacent regions of the Atlantic Ocean, and some work on the West Coast of the United States, and in Australia, no intensive studies of tunas have been undertaken, except by Japanese scientists. Japanese fishery scientists, who were very active in studying the tunas prior to the war, directed some attention to the study of the life history and racial distribution of the Pacific tunas, but their primary attention was directed towards elucidating the distribution and ecology of the several species for the purpose of expanding and developing the fishery for them. Research into those aspects of the biology of the tunas which are essential to developing an understanding of the population dynamics of the stocks of those species, and upon which any conservation, national or international, must be based, has been generally scanty everywhere. There has, however, been notable recent progress in this field. It is with this category of recent tuna research that this paper will be primarily concerned.

Although all sorts of knowledge about the tunas is of value to their wise utilization, certain aspects of their biology are of basic importance to fisheries development and management, such as the limits of independent populations, and the factors determining the abundance of fish in a population and fluctuations therein. It will be a long time before we have a complete understanding of these aspects of the biology of the tunas, but some fragments are beginning to emerge.

RACIAL STUDIES.

Of basic importance to the management of any fishery is a knowledge of the units—called "races", or "stocks", or "populations"—into which the species is separated. Such a unit is composed of individuals, inhabiting a certain part of the sea, which freely intermix and interbreed with each other, and which intermix and interbreed with members of other units little or not at all. These population units must be treated as entities in any plan for developing and managing a fishery. A fishery, however intense, on one population will have no effect on other, unfished populations of the same species. Conversely, where a single population inhabits a large region, fishing in one part of the region has a direct and important effect on the population in every other part. We thus perceive the importance of determining whether each species of Pacific tuna is separated into several separate populations or is composed of a single, vast, ocean-wide population.

The solution of this problem is being approached primarily by means of comparing measurements of body form of tunas from different areas of the Pacific. Since it appears impractical to have one person or one team of persons take similar measurements on specimens of one species of tuna from all the widely separated places where they occur, it has been necessary to attempt to standardize the measuring technique so that data gathered by different observers in different places may be comparable. The basis of this standardization among American workers has been the list of dimensions and counts employed by Godsil and Byers (1944) in their systematic study of the California tunas. Marr and Schaefer (1949) have redescribed these dimensions and counts, as well as several additional ones which may be useful, and have set forth methods of taking them. It is hoped that these measurement methods will become fairly standard among workers elsewhere in the Pacific.

The analysis and comparison of measurement data on the body form of tunas is troublesome, even when the original data are all taken in a comparable fashion. Since, as is well known, the ratio of the size of one body part to another changes with the size of the fish as it grows, such ratios cannot be compared directly without suitable correction for this factor. Schaefer (1948) in describing the relative growth of Central American yellowfin tuna (*Neothunnus macropterus*) and Schaefer and Walford (1950) in comparing body dimensions of yellowfin tuna (*Neothunnus*) from the Atlantic and Pacific, have based such correction on linear regressions between one dimension and another, or between such dimensions transformed according to some simple mathematical formula. Godsil (1948) dealing with extensive data on Pacific yellowfin tuna and albacore (*Thunnus germo*) has employed a simple carvilinear relationship between dimensions for the same purpose. These procedures, while probably the best available, must yet be employed with caution, because they cannot completely correct the data for size-connected variations which may then be confused with true population differences. This difficulty arises from the fact that the regression equations employed represent straight lines or simple curves which can be at best but good approximations to the complex true relationship between the variables. Thus it may be, in comparing body

dimensions of samples of differing size composition, especially where large samples make detection of small differences possible, that even with a correction for variation of dimension with fish size, there will be found differences due to the residual difference between the equation chosen to represent the relation between variables and the true (unknown) relationship, in addition to the real difference between populations which we are trying to measure. Thus, for example, Godsil (1948) has found differences between repeated samples from the same region (and presumably the same population) greater than those attributable to chance. He has explained this on the basis of a presumed difference between schools due to lack of complete mixing between schools of different history in early development, but this seems to us unlikely. Whatever the cause, however, biological or merely procedural, the phenomenon is real and must be dealt with. The means of doing so will not be gone into in detail here; in essence it will consist either of employing as a standard the observed variation between repeated samples from a locality, or of selecting samples for comparison so that they are of nearly equivalent size composition, with the latter being perhaps somewhat preferable theoretically.

The work of Godsil (1948) has indicated that both the yellowfin and albacore tuna of the American West Coast are probably racially distinct from those of Hawaii and from those of the western side of the Pacific. His samples from other than the American West Coast were, however, very small and further verification is indicated.

The author is presently engaged in analysis of fairly extensive data on Hawaiian yellowfin tuna to compare with those from the American West Coast and elsewhere. We have for comparison also a small sample from the Society Islands, a few sets of measurements from Japan, and a few from the Phoenix and Line Islands. From the latter places more specimens are currently being collected by POFI research vessels. Our analyses have not, as this is written, progressed far enough to permit even tentative conclusions to be drawn. In addition to these data on yellowfin tuna, we have collected and commenced analysis of sizeable samples of Hawaiian skipjack (*Katsuwonus pelamis*) and big-eyed tuna (*Parathunnus sibi*) to serve as a basis of comparison with measurements of specimens from other parts of the Pacific. We shall, as these studies progress, begin to obtain an idea of the population divisions of the Pacific tunas.

AGE AND GROWTH.

The population dynamics of a fish stock are intimately connected with the age and rate of growth of its members. A population of a slow-growing, long-lived species is less subject to fluctuations in abundance due to variations in size of entering year classes than is a population of a fast-growing, short-lived species. Where the population is composed of many age groups which go through life slowly, failure or super-abundance of a single age group has small effect on the total stock of fish. Where the population is composed of but a few age groups, variations in abundance of one of them has a relatively large effect on the total stock.

Studies of the age and growth of Pacific tunas have been very meagre. Kishinouye (1923) believed that "The growth of tunnies seems to be very rapid", and that *Thunnus orientalis, T. germo,* and *N. macropterus* reached a meter in length and about 11 kilos in weight in two years. Aikawa and Katō (1938), however, deduced a rather slower growth from their studies of age based on rings on the vertebrae which they took, albeit without much apparent justification, to be annual markings. Brock (1944) concluded from studies of length-frequency data on albacore landings that "only a few year classes are present in the temperate water fisheries for this species, and that these are immature". I have previously published (Schaefer 1948) some rather scanty length frequency data for *N. macropterus* taken off Costa Rica, from which it appears that in the spring months there is a distinct mode near 60 cm. and another near 85 cm. which were believed to be most probably composed of one year old and two year old fish, respectively.

Sampling of tuna catches to determine size composition of the populations which they represent is peculiarly difficult because, like some other pelagic fish, they tend to school by size. It is important, therefore, to sample many schools, rather than merely to measure many fish, if the sum of the samples is to be representative of the whole population. We were very fortunate to discover shortly after we began our tuna studies in the Hawaiian area that the local flag-line fishery and the system of marketing the fish caught by it provided almost ideal ready-made size frequency data for the yellowfin and the big-eyed tuna (*Parathunnus sibi*) of the large sizes which that fishery pursues. The fishery is conducted by means of set lines which are fished twenty to thirty fathoms below the surface and catch large yellowfin and big-eyed tunas, marlin, swordfish, and a few albacore. Each line captures only a few fish each day, so that in the aggregate the catch of the fishery samples rather widely the tuna population present at the depths fished. The fish are sold at auction, one fish at a time, and the auction market which handles about 80% of the landings at Honolulu has kept for the past two

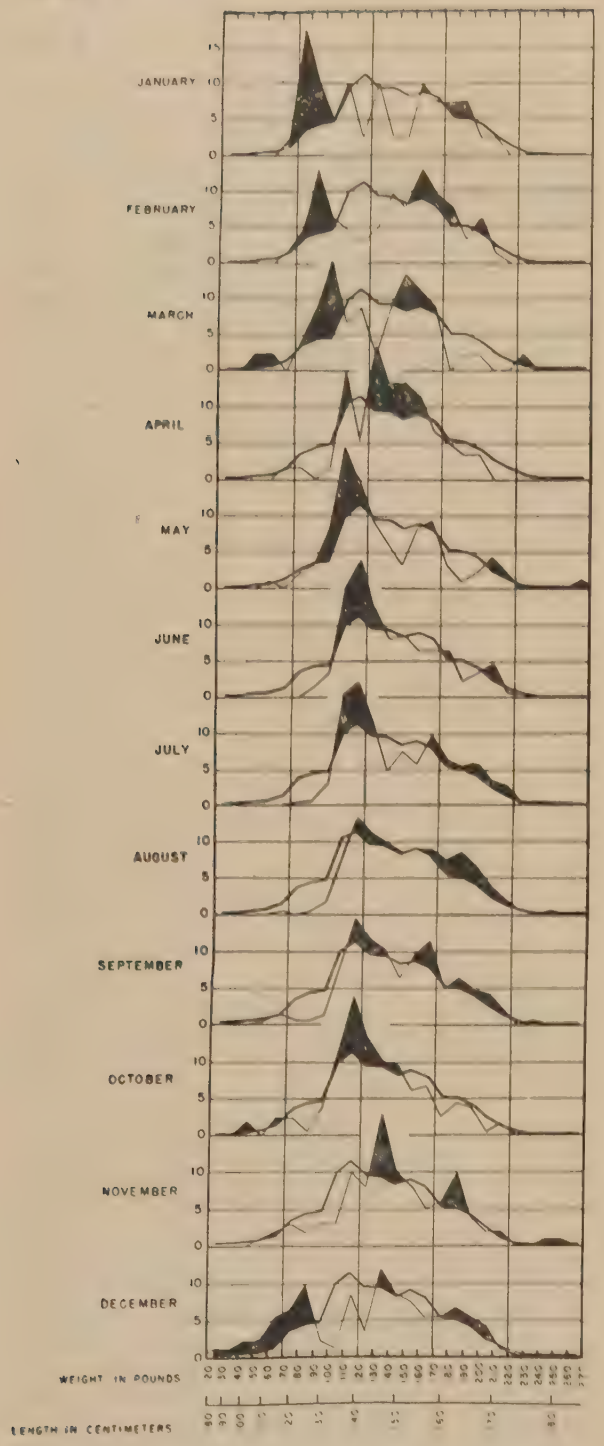


Figure 1. Monthly percentage size frequency distributions of flagline landings of yellowfin tuna at Honolulu, and deviations of monthly distributions from the year's average, for the year 1948. (Fine line, monthly frequency distributions. Heavy line, year's average frequency distribution. Positive deviations of monthly distribution from year's average shaded).

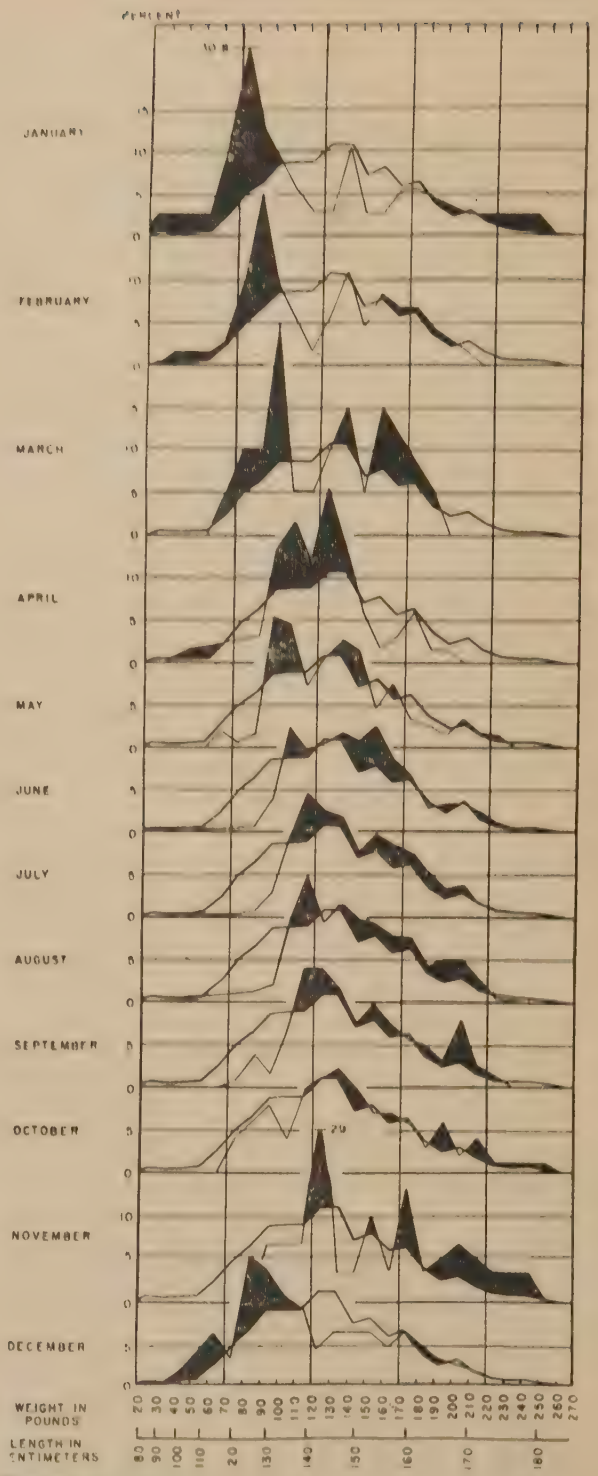


Figure 2. Monthly percentage size frequency distributions of flagline landings of yellowfin tuna at Honolulu, and deviations of monthly distributions from the year's average, for the year 1949. (Fine line, monthly frequency distributions. Heavy line, year's average frequency distribution. Positive deviations of monthly distribution from year's average shaded).

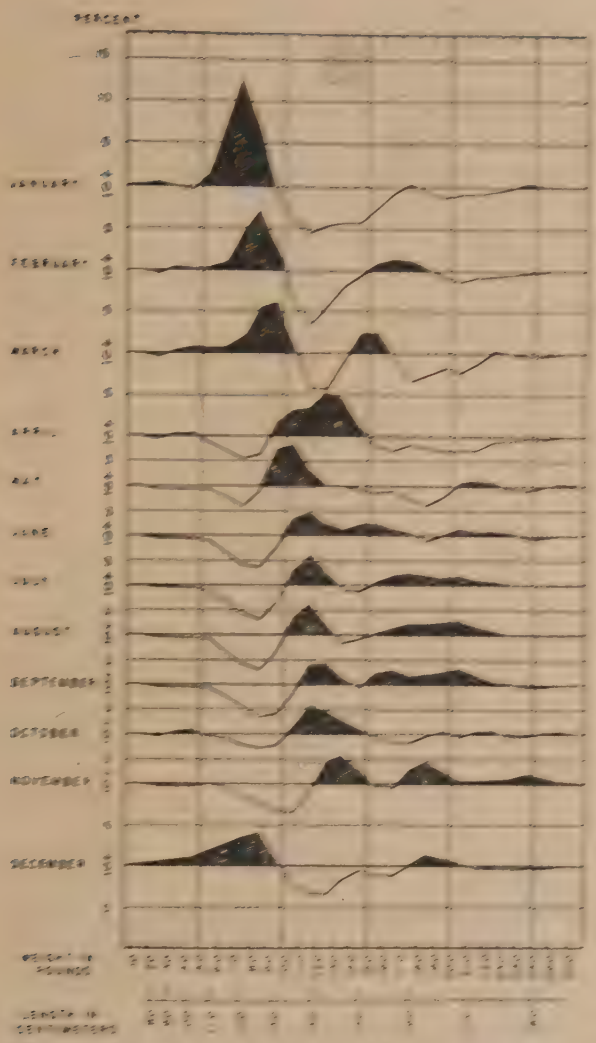


Figure 3. Deviations of monthly percentage size frequency distributions from the average percentage size frequency distribution of all 1948 and 1949 samples of yellowfin tuna taken by flag-line

years records of the species and weight of each fish handled. Thus we have available weight-frequencies for each month consisting of large, well distributed samples of the tuna population available to the long-line fishery. Mr. Harvey Moore of the FCPI staff is engaged on the detailed analysis of these data, which he has assembled from the records of the market in question. The figures presented here were prepared by him as part of a detailed study which will be completed and published later this year. In figures 1 and 2 are plotted the frequency distributions by sizes of each month's catch of yellowfin tuna, on a percentage basis, with the average curve for the year superimposed on it. Positive deviations of the month's curve from the average are shaded to make the modes easily followed. It is easily seen that a group of fish appears in the fishery in December and January at a weight of 70 or 80 pounds and can be followed through month by month until by the time they are a year older the modal weight is in the neighbourhood of 130 pounds. This mode is more clearly brought out in figure 3 where the yellowfin tuna data for both years are combined and plotted as deviations of the frequency curve for each month from the average of all data. There can be no doubt that this mode represents an age group of fish growing in one year from an average weight of about 75 pounds (at a length of 120 cm.) to a weight of about 135 pounds (at a length of 142 cm.). The length scale at the bottom of these graphs represents the lengths in centimeters corresponding to the weights in pounds on the scale above according to the relationship

$$\log L = 1.45660 + 0.33296 \log W$$

obtained from a sample of 200 fish representing the range of sizes encountered in the Hawaiian region both in the flag-line and live bait fisheries.

These data confirm the previous conclusion that the yellowfin tuna are very rapid growers. If the hypothesis, based on my previous Costa Rican data, is correct that this species at one year old is about 60 cm. in length and at 2 years old is about 87 cm. in length, and if Hawaiian fish grow at about the same rate during these years, the fish of the age group making up the mode in question are probably either in their third year or fourth year of life. In any case, with respect to yellowfin tuna we seem quite safe in concluding at this stage of our research that (1) they are very rapidly growing fish, (2) the tuna that are taken in the live bait fishery (fish up to 100 pounds in weight) are very young fish, and (3) both the surface fishery by live bait for the very young tunas and the flag-line fishery for older fish are dependent at any one time on only a few age classes which make up the fishable stock.

Current studies, by Mr. Vernon Brock of the Territorial Division of Fish and Game, which I hope will see publication in the very near future, indicate that the skipjack are likewise young, fast growing tunas and that in Hawaiian waters two age classes constitute the bulk of the stock during a given fishing season.

The fact that a tuna stock is composed of only a few age groups has the important implication that if the recruitment fluctuates very widely the stock may also be expected to exhibit large fluctuations since there is lacking the "buffer" action of many other age classes to dampen out the effect of variations in recruitment. This becomes more important

economically to the fishery the more intense the fishing becomes, because at high levels of fishing the catch cannot be greatly increased by simply stepping up the fishing effort in a poor season.

SPAWNING HABITS.

The likelihood of fluctuations in recruitment depends to a large degree on the spawning habits of the tunas. If a single population of tuna spawns over a wide area and a long season, fluctuations in environmental conditions are much less likely to give rise to large variations in survival and be reflected in the recruitment than if spawning takes place only on one spawning ground during a short season.

The spawning habits of the Pacific tunas have been quite obscure until very recently. Yellowfin, skipjack and black skipjack (*Euthynnus lineatus*) as well as frigate mackerel (*Auxis thazard*) were found in 1947 to spawn during the early spring off Costa Rica and Panama (Schaefer and Marr 1948a, 1948b). Marr (1948) also demonstrated that both the yellowfin and skipjack spawn in the region of the Marshall Islands during the summer. As I noted in another paper (Schaefer 1948) there are references by several authors to evidence of tuna spawning near Japan, Hawaii, Palau, and the Solomon Islands. Juvenile specimens of *E. yaito* and *Auxis* sp. were noted also from material collected by A. W. Herre at Celebes. Papers by De Jong (1940), Delsman (1931), and Delsman and Hardenburg (1934) describe eggs and larvae of *Euthynnus alleteratus*, *Neothunnus rarus*, and *Thunnus thunnina* from the Java Sea. Papers in Japanese, recently translated by POFI translators, such as Kishinouye (1919) and Hatai et al (1941) give evidence of several species of tuna spawning both in the waters adjacent to Japan and in the waters in the region of the Pacific Trust Territories (former Japanese Mandated Islands). Juvenile skipjack captured near the Hawaiian Islands have recently been described by Eckles (1949). Other, smaller specimens of this species have since been captured by scientists of the Territory of Hawaii Division of Fish and Game. Occurrence of females of *K. pelamis*, *N. macropterus* and *P. sibi* in advanced stages of maturity in Hawaiian waters during the spring and summer months, and the collection last year of a running ripe female *K. pelamis* and a very nearly running ripe female *N. macropterus* from these waters by scientists of our staff prove conclusively that these species spawn in these waters, and it seems likely from the evidence of gonad examinations that the spawning season of each is fairly extended here. Wade (1949) has recently described juvenile *Auxis* from Philippine waters, and has advised us in personal communications of the capture by tow nets of about 2000 specimens of larval stages of various tunas and tuna-like fishes.

It begins to appear that the Pacific tunas spawn in many parts of the Pacific, indeed it seems they may spawn throughout much of their range. The next step is to find out how extensive in time and space is the spawning in a single region. This we are undertaking to do in the region of the Hawaiian Islands by means of systematic study of gonads of females in the commercial catch and by tow net collection of eggs and larvae. During the spawning season this spring and summer we shall attempt to find out about the vertical distribution and the rate of development of the eggs and larvae. If this attempt is successful we shall then be in a position to conduct quantitative spawning surveys by means of tow net sampling in subsequent years.

Compared to our knowledge of many of the commercially important species of the northern seas, the halibut, cod, plaice, salmon, herring, haddock, etc., our store of knowledge of the Pacific tunas as indeed pitifully small. The efforts that have recently been expended towards rectifying this have, however, met with at least initial success. The cooperative efforts to fishery scientists throughout the Pacific promise to provide an early solution to many of the mysteries of long standing regarding the basic biology of the Pacific tunas.

LITERATURE CITED

AIKAWA, H. & M. Kato, (1938).—Age determination of fish (Preliminary report 1). Jap. Soc. Sci. Fish., *Bull.*, 7(1):79-88. [In Japanese]

BROCK, V. E.. (1944).—Contribution to the biology of the albacore (*Germo alalunga*) of the Oregon Coast and other parts of the North Pacific. *Stanford Ich. Bull.*, 2(6):199-248.

DE JONG, J. K., (1940).—A preliminary investigation of the spawning habits of some fishes of the Java Sea. *Treubia.* 17(4):325-326.

DELSMAN, H. C., (1931).—Fish eggs and larvae from the Java Sea. *Treubia.* 13(3-4): 407-409.

————, & J. D. F. Hardenburg, (1934). — Die Indische zeevischen in Zeevisscherij. Biblio. Nederl. Indisch. Nat. Ver., (6): 330-343.

ECKLES, H. H., (1949).—Observations on juvenile oceanic skipjack (*Katsuwonus pelamis*) from Hawaiian waters and sierra mackerel (*Scomberomorus sierra*) from the eastern Pacific. U. S. Fish and Wildlife Service, *Fish. Bull.*, (48): 245-250.

GODSIL, H. C., (1948).—A preliminary population study of the yellow-fin tuna and the albacore. Calif. Div. Fish and Game, *Fish. Bull.*, (70): 1-90.

————, & R. D. Byers, (1944).—A systematic study of the Pacific tunas. Calif. Div. Fish and Game, *Fish. Bull.*, (60): 1-131.

HATAI, S. et al., (1941).—A symposium on the investigation of skipjack and tuna spawning grounds. *South Sea Science*, 4(1) 64-75, [In Japanese]

KISHINOUYE, K., (1919).—The larval and juvenile stages of the Plecostei. Sci. Fish. Assoc., *Proc.*, 3(2): 49-53. [In Japanese]

————. (1923).—Contributions to the comparative study of the so-called scombroid fishes. Coll. Agric. Imp. Univ. Tokyo. *Jour.*, 8(3): 294-475.

MARR, J. C., (1948).—Observations on the spawning of oeanic skipjack (*Katsuwonus pelamis*) and yellowfin tuna (*Neothunnus macropterus*) in the northern Marshall Islands. U.S. Fish and Wildlife Service, *Fish Bull.*, (44): 201-206.

————————, & M. B. Schaefer, (1949). — Definitions of body dimensions used in describing tunas. U. S. Fish and Wildlife Service, *Fish. Bull.*, (47): 241-244.

SCHAEFER, M. B., (1948).—Size composition of catches of yellowfin tuna (*Neothunnus macropterus*) from Central America, and their significance in the determination of growth, age, and schooling habits. U. S. Fish and Wildlife Service, *Fish. Bull.*, (44): 197-200.

————————, & J. C. Marr, (1948a).—Juvenile Euthynnus *lineatus* and *Auxis thazard* from the Pacific Ocean off Central America. *Pacific Science*, 2(4): 262-271.

————————, (1948b).—Spawning of yellowfin tuna (*Neothunnus macropterus*) and skipjack (*Katsuwonus pelamis*) in the Pacific Ocean off Central America, with descriptions of juveniles. U. S. Fish and Wildlife Service, *Fish. Bull.*, (44): 187-196.

SCHAEFER, M. B. & L. A. Walford, (1950).—Morphometric characteristics and relative growth of yellowfin tuna (*Neothunnus albacora*) from the Atlantic Ocean off Angola, and comparisons with yellowfin tuna (*Neothunnus macropterus*) from the Pacific Ocean off Central America. U. S. Fish and Wildlife Service, *Fish Bull., In press.*

WADE, C. B., (1949).—Notes on the Philippine frigate mackerels, family Thunnidae, genus *Auxis*. U.S. Fish and Wildlife Service, *Fish. Bull.*, (46): 229-240.

4

BACTERIA IN MARINE ENVIRONMENTS

by

E. J. Ferguson Wood*

ABSTRACT

The main difficulty of marine bacteriology is to explain the way in which the small number of bacteria which can be detected in the open sea brings about the transformations usually ascribed to it. Even in muds this difficulty occurs. It is suggested in this paper that the bacteria do not act directly as much as by producing catalysts or by creating the conditions for reactions which catalysts already present may carry out. The bacteriological work of the Division of Fisheries is testing these hypotheses.

Studies on marine bacteria are numerous, early work being concerned with their numbers, and later work with their taxonomy and function. Zo Bell and Feltham (1934) consider that there are specific marine bacteria which differ from land bacteria in their ability to thrive in seawater. They contend that sea water is bactericidal to land forms, but Waksman and Hotchkiss (1937) have shown that it is also bactericidal to marine forms. I consider, from my own quite extensive work, that the existence of true marine forms is extremely doubtful, and believe that one can trace a gradation from soil forms through the estuarine flora, which also has something in common with the flora of fish spoilage, to the gram-negative marine flora recorded by Zo Bell and his co-workers. The change from gram positive soil types to the gram-negative flora which normally pre-ponderates in fresh water is analogous with the transition from the largely gram-positive mud flora of estuaries to the gram-negative flora characteristic of the sea. There are times in each case where a mixture of types occurs, and except far from land, this is usual. I have found also that many soil forms will grow or can be trained to grow on seawater media while oceanic forms usually adapt themselves to freshwater media. In terms of genera, the genus *Bacillus* which is common in soils, is also common in estuarine muds, but rare in the sea itself. The genus *Corynebacterium* is frequent in soils and *C. globiforme*, etc., are common in the sea. Many of the gram-negative marine forms seem to belong to the genus *Mycoplana* described by Gray and Thornton (1928) from soil, and to the ubiquitous genus *Pseudomonas*. *Micrococcus* occurs in both environments as does *Sarcina*. The unique *Sporosarcina ureae* recorded by Gibson (1935) in soil has been found by me in the sea ten miles offshore. I should say that the truly marine bacterial flora is an adapted flora rather than a distinct one. To clinch this point, we are now studying the flora of the continental shelf, but the recent loss of our research vessel has prevented me from having this final piece of evidence to discuss at this Meeting, although we have found the usual marine *Mycoplana* in muds of the Australian continental shelf. In addition to the heterotrophic flora, the autotrophic flora is common to both environments, e.g., the purple bacteria, *Azotobacter*, *Clostridium pasteurianum*, etc.

The question of numbers of bacteria in the sea is an awkward one; most observers find only a few bacteria in the sea except near land and in plankton swarms, but these observations have been made by cultural methods. Cultural methods usually reveal only a small fraction of the total bacteria present in a given sample, and we have been trying to find some relationship between the number found by these methods and by direct counting. A further difficulty is that, even in freshwater, the distribution of bacteria does not follow the theoretical Poisson series, and duplicate samples can give a wide variation. So far we have not succeeded in finding a relationship, and I think we may safely conclude

* Bacteriologist, Division of Fisheries, C.S.I.R.O. Australia.

that no such relationship exists. My figures seem to suggest that the culture count approaches the direct count more closely as the number of bacteria present decreases. This is possibly due to the more even distribution of bacteria (i.e., less clumping) in the case of smaller populations.

It is generally conceded that most bacteria in the sea are associated with surfaces, and, in the open sea, these surfaces consist largely of microscopic particles. Once a bacterium adheres to a particle, surface phenomena come into play between the bacterium and the particle. If the particle is inorganic, the adsorption phenomena on its surface will depend on its charge. Nutritive substances may or may not be adsorbed on it, and it may thus become a source of concentrated food material, stimulating the reproduction of bacteria which will multiply on its surface. Toxic products from the bacteria may be adsorbed, thus limiting the number of bacteria which continue to exist on it, or may be removed in solution, removing factors which would inhibit bacterial growth. This probably accounts for reports of different authors that the adsorption of bacteria results in their depletion and in their increase. Rubentschik *et al.* (1936) have pointed this out.

If the particle is organic, the situation is more complicated. Surface charge may vary over parts of the surface. The particle itself may serve as food for bacteria, and as long as toxic products are removed in solution or by adsorption, rapid increase in the number of adsorbed bacteria will occur.

From all this it follows theoretically that the number of bacteria per particle will depend on the nature of the particle. Because, in cultural methods of estimating bacterial populations, each particle will usually give rise to one colony of the dominant organism, and since it is the number of colonies which is counted, a constant relationship between cultural and direct methods would not be expected.

Table I shows the direct and plate counts of the same series of samples from estuarine muds taken over a 4 months' period.

In the case of a small population of bacteria, direct counting methods have serious limitations and so far have not proved practicable in the open sea. Perhaps the ultra centrifuge, which we have recently acquired, will help us with this problem, but it may still prove very difficult to separate minute organic particles, bacteria and microflagellates. Differentiation between katabolic (heterotrophic) bacteria and anabolic (autotrophic) microflagellates and bacteria is important on account of the different functions they perform, and it is the function of these various organisms that is the real study of marine microbiology. We know that photosynthetic organisms act as the food source for all animal life in the sea, except perhaps for bacteria which may be used directly as food by animals. It seems reasonable to believe, however, that weight for weight, bacteria are a relatively unimportant source of food compared with the photosynthetic organisms. Bacteria, however, function as katabolic agents returning complex organic matter to the inorganic or simple organic materials which the plants can use. It has been considered in the past that bacteria alone can bring about this transformation and the puzzle has been to reconcile the small numbers of bacteria in the open sea with the amount of material which is known to be transformed. It has been thought that this could be explained by the transformation occurring at the bottom of the sea, but it is doubtful whether very much of the decomposing organic matter ever reaches the sea bottom, except on continental shelves.

Even if one concludes that the ratio of direct to culture count of bacteria is of the order of 1000 to 1, and this seems to be true only for high bacterial populations, and where solid particles are numerous, it seems doubtful whether there are sufficient bacteria in the sea to produce the chemical changes that are ascribed to them. To what then are we to look for these changes? Kreps (1934) and Keys, Christensen and Krogh (1935) and others have suggested that there are free enzymes in the sea. These ideas are based on the activity of water sterilized by filtration through a bacteria-proof Seitz filter or by mercuric chloride. Mercuric chloride, however, is an enzyme poison, so that seems to rule out the possibility of bacterial or autolytic enzymes causing the transformations observed by Kreps (1934), Keys *et al.* (1935) and Cooper (1935).

Two other theories seem to me to be possible:—

1. Non-specific organic or inorganic catalysts may be produced by bacteria and adsorbed by particles in the sea. These substances would then be cumulative and would not be directly related to the bacterial population. They could persist after the decline of the bacterial population.
2. Bacteria may produce conditions which favour certain reactions and these reactions may be catalysed by substances which exist in the substrate. Particles in the ocean would then serve not only to facilitate bacterial reproduction, but would increase the surface available for the action of adsorbed catalysts. The reaction would continue in terms of mass action as long as one of the products was removed by adsorption, precipitation, etc., and as long as the conditions were unaltered.

In either of these ways, small numbers of bacteria could produce a considerable effect, greatly in

excess of that expected by extraction of the bacterial population.

In the presence of plankton organic conditions would be suitable for very great bacterial activity which can be shown to occur and would also facilitate the activity of enzymic or catalytic processes.

I have found in my studies of these problems that I could not devise an adequate method of studying the reactions of such a sparse bacterial population as occurs normally in the open sea. Ordinary bacteriological methods require the use of macro-methods which are not nearly sensitive enough for such work. We have, therefore, turned our attention to muds where the environment differs somewhat from that in the open sea, but where the same general factors may, as a first hypothesis, be assumed to apply. We have assumed for the time being that the action of smaller mud particles will prove to resemble that on particles in the open ocean, and that study of bacterial activity in the presence of these particles will give us a clue to what is happening in the open sea. This work is only in its very early stages so I cannot even hazard a guess on the correctness of these assumptions.

As shown in Table I, we have found that the viable count of bacteria in mud is often many times the culture count, that bacteria are mainly adsorbed on particles, and that the number of bacteria adsorbed upon a particle has no relationship to the size of the particle, i.e., small particles may be covered with bacteria while larger particles are bacteria-free and vice versa. We have also found that up to 95 per cent. of bacteria added to and shaken with a sterile mud will be adsorbed on the mud and disappear from the supernatant liquid on settling. The maximum percentage adsorption is reached with about 1 x 10^8 to 1 x 10^9 bacterial per ml. in water suspension, and does not, as might be expected, increase with increasing numbers of bacteria in the suspension. Kolenkow also found this peculiarity. Adsorption also occurs on washed sterile diatomaceous earth, but not to the same extent as on mud.

Increased bacterial activity has been found to occur after adsorption from a nutrient solution in the presence of the solution. This was greater on mud than on diatomaceous earth, but controls showed that this increase was not entirely due to the increased nutriment in the mud. It was found, however, that sterile mud has some activity on sterile nutrient solutions, suggesting that there are present catalysts which are heat-stable to 125°C. for 20 minutes, and therefore cannot be enzymes. It tends to confirm the findings of Kreps and others, though not their interpretation. Further work is projected to study the type and range of reactions, which may occur under these conditions, and to find out, if possible, the nature of these catalysts if such they be. The distinction between enzyme and catalyst may seem unimportant, but catalysts are much more stable than enzymes, usually are not specific, and are not necessarily of organic origin. We have one clue from some work done on manganese oxidation in soils in which it was found that such substances as oxalacetic, citric and malonic acids catalysed this oxidation, which previously was thought to be entirely due to bacterial action in soils.

REFERENCES

CRAPPIN, L. H. W. (1935).—Rate of liberation of phosphate in seawater by the breakdown of plankton organisms. *J. Mar. Biol. Ass. U.K.* 20: 197-200.

GIBSON, T., (1935).—An investigation of *Sarcina ureas*, a spore-forming motile coccus. *Arch. Mikrobiol.* 6: 73-78.

GRAY, P. H. H. and THORNTON, H. G., (1928).—Soil bacteria that decompose certain aromatic compounds. *Cent. f. Bakt.* II. 73: 74-96.

KEYS, A. Christensen, E. H. and Krogh, A., (1935).—The organic metabolism of sea water with special reference to the ultimate food cycle in the sea. *J. Mar. Biol. Ass. U. K.* 20: 181-196 (Woods Hole Ocean. Instn. Coll. Repr.)

KREPS, E., (1934).—Organic catalysts or enzymes in sea water. *James Johnston Memorial Volume*, Liverpool (1937).

KRISSINTSCHIK, L., Rosin, M. B. and Bieljansky, F. M., (1936).—Adsorption of bacteria in salt lakes. *J. Bact.* 32: 11-31.

WAKSMAN, S. A. and Hotchkiss, M., (1937).—Viability of bacteria in sea water. *J. Bact.* 33: 389-400.

ZOBELL, C. E. and Feltham, C. B., (1934).—Are there specific marine bacteria. *Proc. 11th Pac. Sci. Cong.* III.

TABLE 1

Number of bacteria in millions per gm. mud from 13 estuarine stations at surface and 2 feet from 9/3/1949 to 10/6/1949

Date	Level	Method	1	2	3	4	5	6	7	8	9	10	11	12
9/3/1949	Surf.	Direct	452	443	425	667	1248	369	323	321	308	383	339	336
		Culture	0.18	0.36	0.26		0.94	0.64	0.28	0.80	0.68			0.84
	Deep	Direct	320	305	273	436	452	363	498	321	352	339	402	363
		Culture	2.16	0.6	1.48		0.96	3.32	0.98	2.22		1.20	0.82	
13/4/1949	Surf.	Direct	74.2	96.2	73.6	64.0	73.6	107	84.8	97.6	99.2	96.0	35.2	73.6
		Culture	2.26		1.98	1.24	0.96		0.46		0.74		0.80	0.24
	Deep	Direct	75.2	96.2	73.3	64.1	73.6	70.4	104	96.2	134	39.4	62.4	72.0
		Culture	0.12	0.44	0.48	0.30		0.20		0.32	1.90			0.46
8/5/1949	Surf,	Direct	30.4	19.2	14.4	30.8	20.8	14.4	16.0	16.0	32.0	30.8	41.6	1.6
		Culture	1.4	1.8	1.5	0.58	0.64	1.82	1.08	0.54	0.48	1.26	1.04	1.12
	Deep	Direct		4.0	12.8	6.4		1.6	8.8	3.2	3.2	4.0	0.4	1.6
		Culture			0.9	1.74	0.66	1.98	1.04	0.78	0.48	0.56	0.22	0.68
10/6/1949	Surf.	Direct	6.4	3.2	3.2	6.4	1.6		4.0	1.6		11.2		4.0
		Culture	0.08	0.8	0.7	0.48	0.36	0.68	0.50	1.14	1.52	1.56	0.88	0.64
	Deep	Direct		1.4	3.2	3.2	1.6	4.0	4.8	4.8	4.8	1.6		
		Culture	0.12	0.44	0.48	0.30		0.2		0.32	1.90			0.46

5

THE OVERFISHING OF THE EAST AUSTRALIAN TRAWL FISHERY

by

the late W. S. Fairbridge*

ABSTRACT

An account is given (drawn from two other, fuller papers by the author) of the history of the trawl fishery of the Austsralian east coast. Statistics of catch and fishing effort are presented and discussed with data bearing on the general biology of the principal species of the catch (the flathead, *Neoplatycephalus macrodon*) and dealing especially with the age composition of the catch. It is submitted that the evidence presents a convincing case of depletion caused by overfishing.

The substance of this talk is taken from two scientific papers, one of which was published in 1948, and the other is in press. The first paper dealt with the history of the east Australian trawl fishery and the gross catch statistics. The evidence there showed that the trawl fishery was at that time (in 1947) being overfished, and that the size of the fishing fleet would have to be cut by between a third and a quarter before there could be any chance of the fishery becoming stable.

The conclusions were drawn from the catch figures as a whole. These referred to a mixed catch of a number of species, and the catches of individual species were not shown. The more recent paper as yet unpublished, deals with the catch of what was the major species—the tiger flathead—a member of the family Platycephalidae.

In the present talk I shall follow the same line as that taken in the two papers, and describe first the overall history and catch figures of the trawl fishery; and then deal with the age-composition of the flathead catch, and the way in which the stock of this species has suffered under the overfishing.

HISTORY OF THE FISHERY

First, as to the location of the fishery; this is shown in Figure 1. It radiates, as it were, from Sydney, north and south. The narrow shelf, 15 miles wide, has rough bottom within 30 fathoms. There is a strong ocean current.

The furthest grounds are 350 miles south of Sydney. The steam trawlers land fish only at Sydney. The Danish seiners work from some dozen or more ports along the coast. They operate in a radius of about 20 miles from their particular port.

Figure 1.

Figure 2 illustrates the total trawl fish catch throughout the history of the fishery.

The top line is the total catch; the dotted line is the size of the trawling fleet. The lowest line represents, roughly, the catch per boat, obtained after expressing the Danish seiners and steam trawlers in comparable units.

* Late Biologist, C.S.I.R.O. Division of Fisheries, Australia.

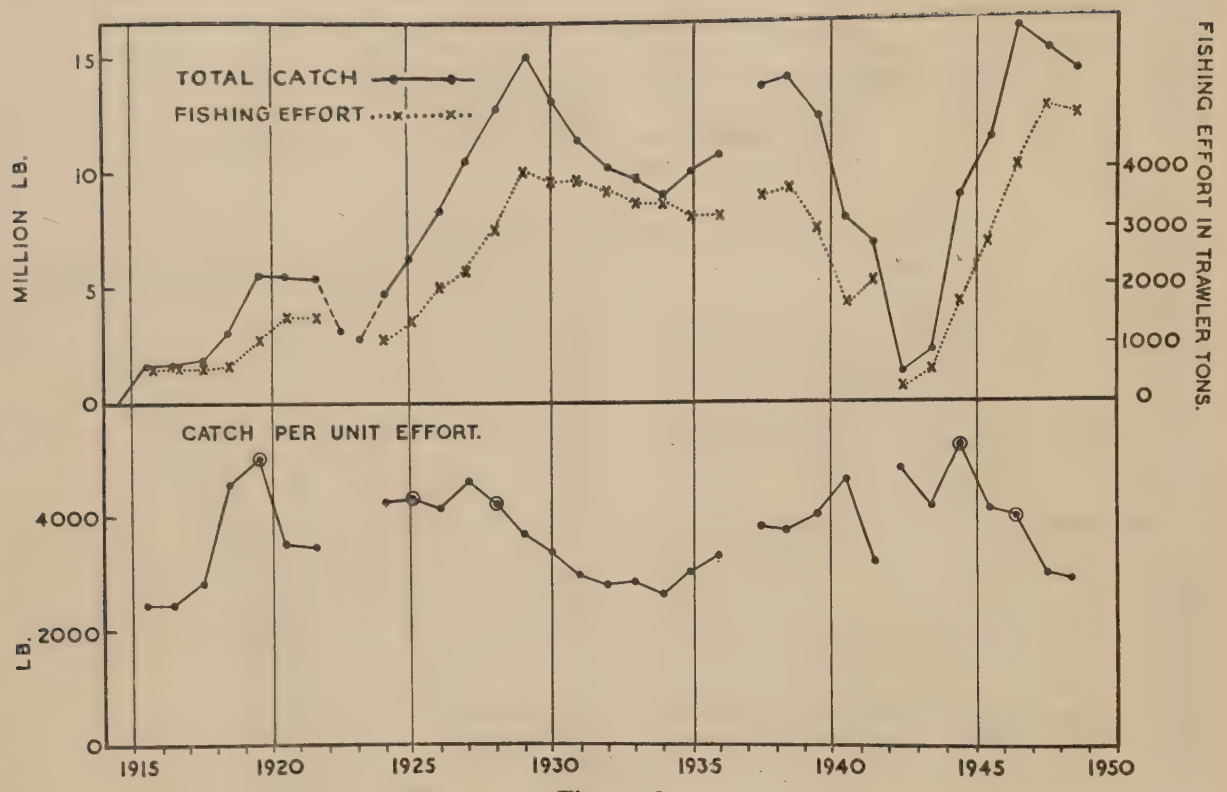


Figure 2.

The Australian trawl fishery had its beginnings in 1909 when H. C. Dannevig, of Norway, in the steam trawler "Endeavour" was commissioned by the Commonwealth Government to explore the trawling possibilities in this country. This exploratory work was carried on for five years, covering most parts of the eastern and southern seaboards of Australia, until the "Endeavour" was lost with all hands in 1914.

As a result of Dannevig's discoveries, the New South Wales State Government brought out some steam trawlers from England, and trawling was begun as a Government enterprise.

A start was made of trawling in 1915 with a fleet of 3 trawlers, which later was increased to 7. In 1922 business was handed over to private firms. More trawlers were brought out, and the catch rose to 15 million pounds in 1929. By the 'thirties the catch was falling, partly as a result of reduction in fleet, partly as a result of falling catch per boat.

By 1930 all the grounds that are now fished had been opened up. The falling catch per boat presumably was due to the heavy fishing. The catch per boat had been falling since 1927, although the total catch did not fall till after 1929.

But by 1935 the fleet had been reduced to 13 trawlers, and both the total catch and the catch per boat had begun to rise. I have therefore suggested that a fleet of this size is rather close to the desirable level. The catch at this time is not the theoretical optimum catch. But at this level of fishing intensity the catch was beginning once more to expand, and we may therefore regard the size of the fleet as a sort of *Empirical Optimum*.

However, about 1937 and 1938 Danish seining was introduced into these waters, and the fleet began to expand.

The catch, too, began to expand (though figures are suspect here), but the rate of catch suggests the beginning of a decline as one would expect if the fishery was indeed just beginning to recover from overfishing.

This point cannot be proved, because the war began to affect things in the year 1939/40, after which the size of the fleet and of the catch were falling, and the catch per boat rising.

The trawlers were being requisitioned during the war for mine-sweeping. In 1942, the very considerable fleet of Danish seiners was requisitioned for use in the war against the Japanese. This resulted

in a period of rest for the fish stocks. The extent of this rest may be expressed as two years of moderate catch, two years of very low catch, and then another year of moderate catch.

With the end of the war the trawling fleet began to increase; and in the flush of enterprise that followed the war, the total fishing effort reached a peak considerably higher than any hitherto. As was to be expected, the catch rose also to a peak—and then fell. The rate of catch, or the catch per boat began to fall almost immediately after the war; it has been falling now for four years, and is now about as low as it has ever been.

These results were felt at the time in 1948 to be quite expected, and typical of an overfished fishery.

That is the burden of the main conclusions that can be drawn from the gross catch statistics; but it is necessary to stress that these figures all relate to total catch: that is, to *all* the fish species taken by the trawlers. We now know that the gross figures are concealing some very interesting changes in the stock of what was the principal species—the flathead.

The rest of this talk is therefore more concerned with the fluctuating catch of the flathead.

BIOLOGY OF FLATHEAD

Our research into the biology of the flathead has taken the line, chiefly, of making an estimate of the age-composition of the commercial catch. This, indirectly, involves a complete study of the biology of the species. What follows, then, is a summary of the biology of the flathead, as it concerns the problem of age-determination—and then a brief account of the age-composition of the catch—and these results will be used to re-examine the catch figures.

The geographical range of the flathead is virtually contained within the heavy dark lines which mark off the limits of the trawl fishery. The species therefore occupies a narrow strip of coastline, bounded on the seaward side by the deep Pacific waters, and to north and south by what are apparently unfavourable conditions. The area of greatest natural concentration of the species is off Twofold Bay and perhaps extending up to Ulladulla. To the north and south of this area the flathead stock occurs in smaller concentrations and is less able to withstand heavy fishing. For some reason large numbers do not occur in Bass Strait to the west of Wilson's Promontory; only a few have been taken by trawlers working in that area. In Bass Strait trawling is confined to the eastern shelf.

Spawning is in this species protracted and occurs throughout the six summer months. The egg is planktonic. It has been obtained by artificial fertilization; but it has no markedly distinctive features, and it so closely resembles some other eggs to be found in the plankton in the same months that no work has been done on its distribution in the sea. Similarly, larvae belonging to members of the flathead family have been caught in numbers from time to time. But there are at least half a dozen closely related species occurring in the range of the tiger flathead, and it has not yet been possible to identify the larva of the tiger flathead with certainty.

We know that spawning occurs virtually throughout the entire area of distribution of the flathead, and bearing in mind the strong currents and counter-currents that sweep the New South Wales coast, there can be little doubt that the flathead larvae are distributed in varying numbers throughout the coastal waters, and that genetic uniformity is the rule throughout the flathead stock. It would be interesting to know what proportion of the eggs and larvae is swept out beyond the edge of the shelf and lost. It would seem that the numbers would be considerable. But as yet we have no knowledge about that.

We are next able to pick up the developing flathead at between 5 and 10 cm. in length. Experimental trawling using a finemeshed cover outside the codend has shown that the flathead of less than 3 years old are mostly to be found in the inshore waters of less than 30 or 35 fathoms' depth. We have taken them in numbers in 20 fathoms. But of grounds shallower than this I am afraid we can't say very much. The bottom is mostly rough inside the 30 fathom line, and it is difficult to find any place where one can use a trawl for sampling these younger age-groups. It may be significant that we found the greatest concentrations of these early age-groups in the Twofold Bay area—the area which carries the greatest number of adults. The important point is that this distribution of the young flathead largely places them out of the area of intensive trawling: Looking at it in another way, however, it may be that the intensive trawling kills off the young flathead which make bottom in the deeper water, so that the majority of the ones we found were inside this depth. The truth of this point could be demonstrated only by experimental closure of some of the trawling grounds—to see whether young flathead might begin to be found in the deeper waters under those conditions.

In their second summer the male flathead spawn for the first time, and the females mostly spawn for the first time in the year following.

The maximum size to which the flathead grows is sixty or sixty-five centimetres—but there are few specimens at this size, and to-day the majority are around 35 cm. The minimum legal length of this species is 33 cm. Hence quite a large proportion of

undersized fish is caught—about a quarter of those landed are under the legal size—mostly just under. The legal minimum size was established by the State Fisheries Department before much research had been done on the species, but we have no quarrel with it. A flathead of this size makes reasonable fillets, and it is in fact, about the size at which a high proportion of the flathead begin to be retained in the 3 inch codends. Most of the males have spawned once before reaching this size, and it is about the size at which the smallest females will begin to spawn for the first time.

Age determination

The otoliths have been found to be best for this purpose; but they are not good. It has been found that above a fish-length of 9 cm. the otolith grows in length in proportion to the fish. Length is measured from the centre to the posterior tip. The practice has therefore been made of measuring the intermediate lengths by means of an eye-piece micrometer. This was found to be a great aid in determining the true age of an otolith, in those cases where the record is confused by supernumerary annuli.

Supernumerary annuli are the great difficulty in interpreting these otoliths. The annulus is formed in midwinter. Spawning is in summer. It is not clear what actually causes translucent growth to be laid down in the otolith. But it does seem likely that the poor condition of the fish resulting from spawning during the summer may be an indirect cause of the formation of some of the supernumerary annuli. I have not been able to demonstrate to what extent growth may be correlated with the formation of opaque and translucent material in the otolith. In many fishes in which age-rings are clearly marked in the scales or otoliths, spawning runs into the period of slow winter growth: in the flathead, the two seasons are widely separated, and that may account for some of the irregularity in the annuli.

The otoliths figured in the plate must not be be taken as a fair sample. They have been selected for the clarity with which they show the rings.

The smallest shows no annulus, and the next shows one. The next shows two, and the next three—there is a very small band of opaque material on the very edge. This fish was caught in late June, so it had evidently formed its annulus a little early and had already begun to put on opaque growth. In the next, the innermost annulus cannot be made out clearly in the photograph, but there are three others outside it, making a total of four, with opaque growth on the edge. In the last there are four distinct annuli. The fish was taken in January, so its age would be exactly four years. In all otoliths the first zone of opaque growth represents an incomplete year—between 3 and 9 months.

One of the most important verifications of the validity of such age-determinations was that when we eventually obtained large samples of the smaller age-groups (by means of the experimental trawling), their length-frequencies clearly indicated the representative age-groups, and the modes of these age-groups agreed very closely with the actual calculated intermediate lengths which we had been obtaining for the past year or two, on theoretical grounds, from work on the otoliths.

Growth

From the calculated intermediate lengths obtained from the otoliths we have constructed some approximate average growth-curves.

The material was divided up according to sex and according to locality (Figure 3). It is seen

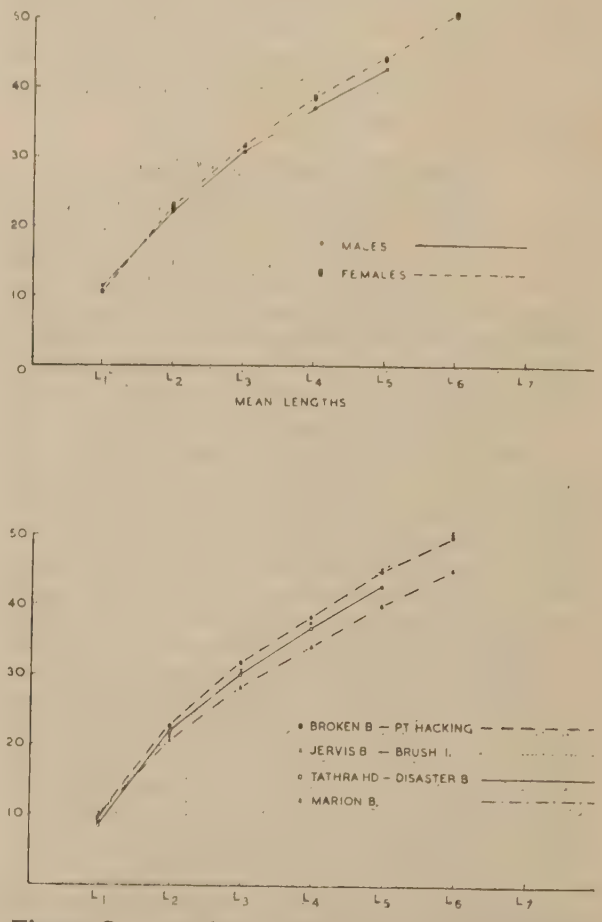
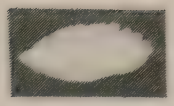


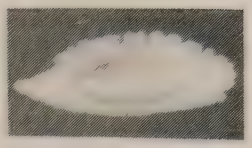
Figure 3. Growth rate of flathead. Ordinates show centimetres; abscisrsae show intermediate lengths.



[illegible]

[illegible]

[illegible]



[illegible]

(7 inches)

[illegible]out to form 2nd. annulus

[illegible]. 1. 46.

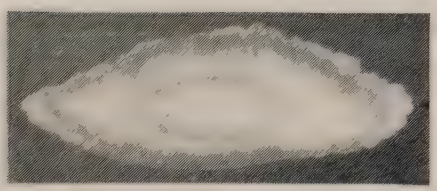
23 mm.

(1 1/4 inches)

[illegible]

[illegible]

[illegible]. 46.

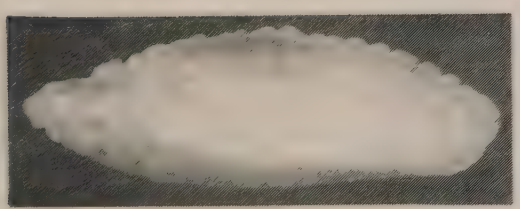


[illegible] mm.

[illegible]

[illegible]complete annuli formed; [illegible]te border shows beginning of quick spring growth.

18. 6. 46.



[illegible] mm.

(1 3/16 inches)

[illegible]

[illegible]. 46.

[illegible] mm.

(1 5/8 inches)

[illegible] annuli; 5th just forming.

10. 1. 46.

Plate 1. [illegible]

that there is a small difference in growth-rate between the sexes. The males grow more slowly than the females. There are also locality differences. The fish from the northernmost localities grow fastest, and those from the south grow slowest. The curves have not been produced down to the origin, because the first increment does not represent a full year's growth.

AGE-COMPOSITION OF THE CATCH

The construction of an average growth-curve was not the primary objective in establishing a method for age-determination. What was aimed at was an analysis of the commercial catch into its constituent age-groups (Figure 4).

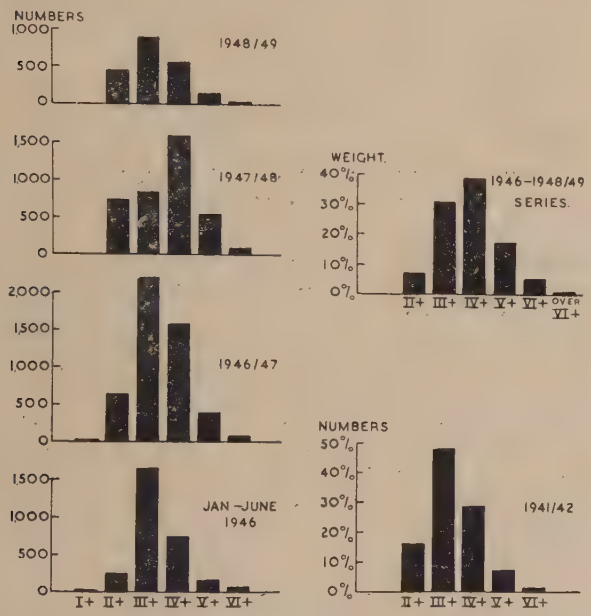


Figure 4.

Sampling of flathead is simplified by the fact that almost all the flathead catch is sold in the Sydney Fish Market. We therefore concentrated on random monthly length samples which were made representative of the whole commercial catch. From about one-tenth of these specimens we obtained otoliths. From the age-analysis of these otolith samples, we were able to weigh the random length samples, so as to get a good estimate of the proportions of each age-group in commercial catches. Since we know the size of the commercial catch in each month we can, from this, work out the actual weight of each age-group, or the actual numbers in each age group, in the commercial catch. The estimates of the catches for the four years on the left of this figure have been obtained in this way. The left hand axis gives the actual numbers of each age-group caught in each year—in millions of fish. The earlier year—1941/42—could not be treated in this way, and the numbers are shown as percentages.

It will be seen that the proportion in which the different age-groups occur is very regular. The III-group is the most important, followed by the IV-group. Only one year is aberrant—1947/48. In that year the IV-group is more important than the III-group. The annual reduction in numbers after the III-group is about 75 per cent, and it gradually increases with age. In the sixth histogram, on the upper right hand side, this material is averaged and the relative proportion of each age-group is expressed in terms of weight. In this case the IV-group is the most important, followed by the III-group.

The important features to notice in this series of histograms are, firstly, the virtual absence of fish over VI years old, and secondly the absence of violent year to year fluctuations in numbers of the different age-groups.

FISHING EFFORT

We can now turn to the actual catch figures for the flathead over the last few years (Table I). This table shows the catch of flathead and of the two other chief species, the morwong and nannygai.

It covers the latter part of the war, and the years since then. It is only during this period that statistics have been collected for individual fish species. And the results are quite startling.

In the first two years shown here there was little fishing effort. (The total fishing effort—in the right hand column—has been obtained by expressing the Danish seiners and steam trawlers in comparable units, and summing the two). The next year (1944/45) saw the maximum catch of flathead, and for the four following years the catch has declined. I want to stress that the actual total catch of flathead has declined, till it is now a little over one-third of the level of five years ago.

On the other hand, the trawlers have had to make up their catches with second and third quality species—the morwong and nannygai. These species were formerly not caught, or at any rate were landed only in very small numbers. The prices of these two species are approximately three-quarters and a half that of flathead.

It is seen that the catch of morwong rose to nearly 4 million pounds. Then it in turn declined in the last year. I repeat that these are actual catch figures, not rate of catch. Actually, the rate of catching of morwong is little more than half that of three years ago. It, too, is probably being overfished at present. Then, taking the nannygai, a

cheaper fish again, it is seen that the catch has risen to 5½ million pounds—it is now greater than that of either the morwong or flathead, and, in fact, the rate of catch is still rising. But it must be obvious that it is only a matter of time before the nannygai also will feel the effects of the heavy fishing.

Meanwhile, the effect of all this on the *total catch* is that there has been an overall reduction of 2 million pounds in the last 2 years.

It must be obvious from this table that we have here to do with a case of very severe overfishing. The fluctuations shown in this table cannot be due to natural population fluctuations—at least, not in the case of the flathead. This possibility was eliminated by the work on the age-composition of the catch.

Since the first paper on the trawl fishery was published (when the catch was still rising and was a record) two years' catch figures have become available; and it is clear that the catch of those two years amply supports the conclusions reached then—namely, *that the fishery was over-exploited, and that unless the fishing effort was reduced, the actual total catch would fall.* This prediction has come true.

But when we come to examine the flathead catch in the past, an even more remarkable and rather puzzling situation becomes apparent. I said that we had no catch figures for individual species in the early years. That is not strictly true. We have some series of old trawlers' logs covering three periods. Now these logs give the *catch of flathead,* and the *total catch* of the individual boats to which they refer. From this we can get the proportion of flathead in the catch of the individual boat. We appear to be on safe ground in assuming that this is much the same as the proportion of flathead in the catch of the whole fleet at the time. These figures are given in Table 2.

It is apparent that the proportion of flathead in the catch shows considerable regularity. Column 3 shows the number of boats from which the proportion was derived. The table has been continued down to recent years to make it complete.

In the early days more than 80 per cent. of the catches were flathead. In the next period (1928-1933) there was a steady reduction in the proportion of flathead from 95 to 65 per cent. This is the period of falling catch per unit effort. In column 4 I have calculated what the actual total flathead catch would have been on this basis, and in column 5 the rate of catch.

In the next period (1937/38-1941/42) the percentage of flathead was still falling, and so continued till the most recent period, until last year there was only 9 per cent of flathead in the catch. (These figures refer only to the steam trawlers, and do not include the Danish seiners).

The astonishing fact is that in the early days—1928, 1929, 1930—even after there had been considerable exploitation of the fishery, the actual (estimated) total flathead catch was between ten and thirteen million pounds. And to-day the total flathead catch is 2.1 million pounds. In the right hand column you have the calculated fall in the rate of catch as it applies to the steam trawlers. The figure to-day is less than one-tenth that of 1930.

What is one to make of a reduction of that magnitude? Can it be explained as merely overfishing?

Further, why was the postwar recovery of the flathead fishery not more pronounced?

This and other questions, which are dealt with in detail in a paper now in the press, can best be explained, I think, on the assumption that in this fishery the number of recruits is largely governed by the number of spawning adults. Hitherto, the reverse has usually been believed true of sea fisheries. As yet it can only be a hypothesis in this case. But I believe that we can explain along these lines the slow, or rather the halting recovery of the flathead stocks as a result of the war-time respite; and also, perhaps, this apparently cumulative effect of overfishing shown by the figures in this table.

The conservation measure which we are advocating, which we have been advocating for the past two or three years, is a reduction of the trawling fleet to about the level of 1935—the point at which the trawlfish stocks as a whole were beginning to show signs of recovery. As an additional measure, we advocate the complete closure of the Botany ground to fishing for an experimental period. That is the ground immediately south of Sydney Heads. It used to carry an enormous quantity of flathead, and flathead still do show up there in numbers at about spawning time. It is felt that this would be a most convenient and useful ground on which to study the effects of closure.

TABLE 1

THE CATCH (IN MILLION LB.) BY THE TRAWLING FLEETS, COMBINED.

	1. Flathead.	2. Morwong.	4. Nannygai.	5. Total Fish.	6. Total fishing effort expressed in thousands of trawler-ton-months.
1942/43.	0.5	0.02	0.1	1.3	4
1943/44.	1.2	0.02	0.05	2.2	6
1944/45.	5.7	0.5	0.1	8.9	20
1945/46.	5.2	2.0	0.8	11.3	34
1946/47.	5.0	3.9	2.0	16.2	50
1947/48.	3.8	3.9	3.5	15.1	57
1948/49.	2.1	3.0	5.5	14.2	57

TABLE 2

TRAWLERS' CATCH ONLY

1.	2. Proportion of flathead in the catch %	3. No. of vessels from which proportion was divided	4. Estimated total flathead catch: millions lb.	5. Catch of flathead per trawler-ton-month
1918/19.	88	7		
1919/20.	87	7		
1921/22.	82	7		
1922/23.	81	7		
1928.	95	1	12.2	367*
1929.	87	1	13.1	295*
1930.	80	1	10.5	243
1931.	80	1	9.1	224
1932.	76	1	7.8	201
1933.	65	1	6.3	174
1937/38.	65	14	7.5	180
1938/39.	62	5	7.2	174
1939/40.	68	8	5.8	204
1940/41.	59	4	2.3	218
1941/42.	41	3	0.9	123
			Actual flathead catch.	
1942/43.	41	1	0.5	157
1943/44.	47	1	0.5	237
1944/45.	38	1–4	0.7	95
1945/46.	29	4–5	1.2	92
1946/47.	22	6–11	1.9	74
1947/48.	19	12	1.9	60
1948/49.	9	12	0.9	25

6

SOME POPULATIONS OF THE AUSTRALIAN "SALMON", *Arripis trutta*

by
the Late W. S. Fairbridge*

ABSTRACT

A preliminary account is given of the investigation of the Australian Salmon (*Arripis trutta*) principally as an examination of the distribution (in all life-phases) of different stocks of the species along the Australian coast, and the taxonomic status of these stocks. Morphological and other evidence is presented to support an hypothesis that the stocks constitute distinct races with separate breeding grounds.

The Australian salmon is a percomorph, and not in any way related to the Salmonidae. The popular name was presumably given to it by the early settlers in this country, on the strength of some superficial resemblances to the true salmons and trouts.

The present paper is only a progress report. The results are not yet fully tested and definite, but it was thought that delegates might be interested as much in the lines along which the work is progressing as in the final results. The story which is emerging is, as a matter of fact, somewhat unexpected; and it is of considerable interest to workers in Australia.

The subject is that of raciation.

In the so-called Australian "salmon" we have a common, well-known species, of which there are several very full taxonomic descriptions. Yet when we come to investigate it, we find that an apparently homogeneous and continuous stock is divisible into two distinct subspecies; and one of those subspecies is probably further divisible into two separate populations. The morphologic differences which we have found between the populations are of standard taxonomic characters, which however the early taxonomists apparently overlooked.

An idea of the appearance of the fish can be got from Plate 2 (upper).

In general the species is used for canning. It is not greatly fancied as fresh fish.

There are two main fishing centres—namely in the south-east and the south-west corners of Australia. The fishery in the south-east is capable of producing about 4 million pounds a year. The fishery on the south-west is of quite recent development, and last year the production was 5½ million lb.

Australian salmon occur in large shoals, usually close inshore. They have the habit of coming close into the beach while in these shoals, especially in certain localities, and it is then that the fishermen catch them.

This is usually regarded as an onshore species. Shoals are not commonly sighted beyond the continental shelf; but there are reports, apparently reliable, of salmon shoals being sighted, and specimens caught, well out in the Tasman Sea.

Figure 1 shows the general world distribution of the species. In Australia it extends up the east and west coasts to about latitude 30°S, though occasionally it is taken very much further north. There is a large, and apparently quite untapped, population of salmon in New Zealand. It occurs also in the waters around Norfolk Island and Lord Howe Island.

When the present investigation was started in 1947 it was believed—for want of contrary evidence—that the salmon of south-east Australia were probably all of one stock, probably distinct from the salmon of south-west Australia. It was believed that the Western Australian fish were in some way different from those of the south-east because of geographical separation, and because the salmon of the south-west are very much larger, and the scales indicate a very much faster growth-rate.

The first and most important discovery of the present investigation was that the salmon from south-west Australia have fewer gillrakers than the salmon of New South Wales. The Western Australian salmon have 25 to 30 gillrakers, and the New South Wales salmon have 33 to 38. Each group shows a spread of about 5 gillrakers, but there is no overlap and, in fact, there is a sizeable gap between the two groups.

This shows that there is indeed a definite difference between the salmon of the west and of the east.

Following quickly on this discovery it was found that some of the juvenile salmon from Tasmanian and Victorian waters also belonged to the group with the low count. In other words, they were distinct from the salmon of New South Wales.

* Late Biologist, C.S.I.R.O. Division of Fisheries, Australia.

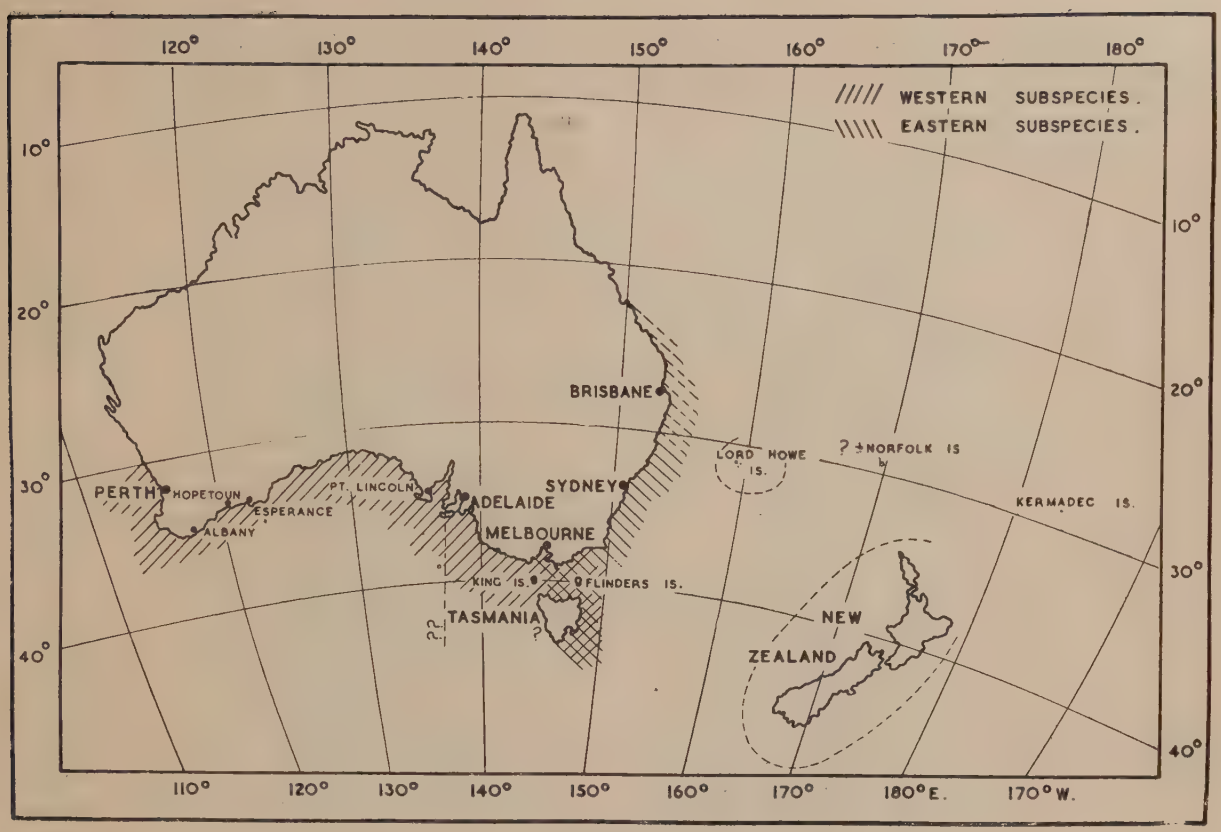


Figure 1

(Hereafter, these groups will be referred to as the western and eastern subspecies—*the western subspecies has 25 to 30 gillrakers, and the eastern has 33 to 38*. These juveniles of the western subspecies which are found in the south-east of the continent, were fish of from 6 cm. length (mere fingerlings) up to 30 or 40 cm. in length (at which size they are several years old). It was found that in Tasmanian and Victorian waters, and in Bass Strait generally, the two subspecies often occurred mixed in the one shoal. Such shoals might be preponderantly of one or the other subspecies.

In Figure 1, the distribution of the eastern subspecies is distinguished from that of the western subspecies by hatching, and the area where the mixed shoals occurs is shown similarly. There is no information yet from the west coast of Tasmania. Though it is known that there are salmon there, it is not known to which subspecies they belong. The zone of mixing of the two subspecies in Victorian waters—between Wilson's Promontory and the south-east corner of the continent—is of some interest. It happens to be the approximate division between two previously well-established zoogeographical areas.

The next step in this work was to obtain samples of salmon from New Zealand and from Lord Howe Island. It had been effectively established by the work on the gillrakers that there was no appreciable interchange between the stocks supporting the fisheries of the *south-east* and of the *south-west*, but it *was* possible that there was interchange between New Zealand and New South Wales waters.

Two good samples of New Zealand salmon (about 50 fish) were obtained; and a small sample was obtained frim Lord Howe Island (about 10 fish). Unfortunately it has so far been impossible to get any fish from Norfolk Island. The samples obtained were compared with New South Wales specimens by means of 18 proportional measurements, and by counting scales, fin-rays, vertebrae and so on.

Though there were so few in the sample from Lord Howe Island, it was apparent that one had to do here with a very different looking fish. The head was shorter than in the others, and the body was much stouter; in addition, the flesh was extremely oily. Oil is very low in Australian salmon at all times of the year, and was low in both of the New Zealand samples. All these characteristics of the Lord Howe

Island fish point to good feeding and fast growth, and that conclusion is confirmed by the scales. Of more importance, it was found that the gillrakers were substantially different in number in comparison with the finding for the eastern subspecies of Australia: they varied between 36 and 41, and this feature seems to distinguish the Lord Howe Island salmon from all others.

The New Zealand salmon were much less distinct from the New South Wales stock than were the Lord Howe Island salmon. However it is almost certain that they are distinct from the New South Wales salmon, because there was a difference of about 1 scale in the girth and about 0.34 in the dorsal ray counts. The material is not yet full enough to eliminate any chance that *sex* and *year-group* may be affecting these meristic counts; but the data do show that if either variable has an effect, it is not of such magnitude as to invalidate the differences in the girth scale count.

The proportional measurements have not yet been tested statistically, but there *appears* to be absolutely no difference between the New Zealand and the New South Wales salmon. The two are undoubtedly very closely allied. There are considerable differences, as stated above, between the New South Wales and the Lord Howe Island salmon, mainly involving the short head and the great girth of the Lord Howe Island fish. Such differences are not necessarily genetic, but might be merely the effect of particularly good conditions in the waters around Lord Howe Island. However there are other differences, such as the *length of the anal fin* and the *diameter of the eye*, which do not seem to be merely the effect of good feeding, but probably mark off the Lord Howe Island salmon as a separate breeding population from the other groups studied here.

Further samples were obtained from Western Australia and, after some difficulty, several dozen specimens from South Australia.

It should be pointed out that all along this study has been hampered by the fact that this species has a very wide distribution. It is usually sporadic in its appearance, and its distribution covers some completely uninhabited stretches of coastline.

As previously stated, there are two centres of the fishery, south-east and south-west. In the south-west, the roads all run inland and not coastwise, and the coastline is desolate. East of Esperance there is nothing but desert. From Adelaide to Melbourne is also sparsely inhabited, with no salmon fishery. The west coast of Tasmania is very desolate, with no fishery. There are therefore many gaps in the records of the species which must be filled in by supposition, or at times by fewer samples than one would like.

The South Australian specimens came from the "Gulf" area. It was found that they agreed very closely with the samples from Western Australia in everything but the girth scale count—and that apparent difference may prove not to be significant when larger samples are obtained.

Even more significant perhaps, was the *growth-rate* of the South Australian salmon, as shown by their scales. The faster growth and larger size of the West Australian salmon, compared with the New South Wales salmon, has been previously mentioned. Though the South Australian fish were young—mostly 2 and 3 year olds—their scales showed a growth-rate that agreed very well with the West Australian salmon.

We may now examine the tables of gillraker counts, girth scales and dorsal rays. These figures do not embrace all the material available, but have been drawn up simply for the purpose of illustration. It must be emphasized that the work is to be regarded as very incomplete as yet.

The samples in this table have been divided up into the possible or suspected discrete populations.

It will be seen that, as far as gillrakers are concerned, there is no doubt about the break between the eastern and western subspecies. There is probably no significant difference between New Zealand and New South Wales, nor between Western Australia, South Australia and south-east Australia.

There is a single instance of a salmon with a high gillraker count taken in Western Australia. Presumably there is *some* admixture between the two subspecies. They have very similar habits, and no doubt cross-breeding might occur between isolated specimens and the main body of fish.

These tables also give the distribution of the two other meristic features which show variability.

Taking the dorsal rays first, the material obviously falls into two groups, corresponding with the two subspecies distinguishable from the gillrakers.

The girth scales, however, are separable into three or four groups. The West Australian counts may or may not be significantly different from those of South Australia, but are significantly different from the eastern sub-species. The New Zealand samples also differ significantly from those from Australia.

Again it is necessary to stress that this material has not yet been fully tested to determine whether age—or year-groups or sex—are causing slight difference between means. But it is known that these factors are not causing large differences, such as are apparent in these tables.

The other obvious meristic features were also counted—vertebrae, and the other fin rays and

Plate 2. (See text, pp. 80 and 84).

spines—but all showed great constancy and little likelihood of being useful. Some other scale counts were made—above the lateral line, and around the caudal peduncle; they seemed to show parallel variation with the girth scales, but because the girth scales could be counted with greater certainty, the other scale counts were neglected.

So far, this paper has been concerned mainly with the taxonomic characters by which the various subspecies and populations may be revealed in this species. But there is a mass of rather scattered information concerning habits, migrations, distribution of young, and so on, which all falls into place if interpreted in the light of the foregoing results.

First of all, in New Zealand it is known there are large numbers of salmon fry which are seen at times in shallow water. This is pretty conclusive evidence that the salmon spawn in New Zealand waters. The same is probably true of Lord Howe Island, where young salmon are taken from time to time. Since the salmon are also known to spawn in New South Wales waters, this is confirmatory evidence that the New Zealand salmon are distinct and independent of the New South Wales stock. As mentioned earlier, there are reports of salmon shoals half way across the Tasman Sea, and it may be that there is some exchange between the populations.

The adults of the eastern subspecies undertake a rather scattered migratory movement. They spend winter and spring in New South Wales, and in summer and autumn move south. They spawn off the southeast corner and apparently move further south, but subsequently move north. The fry are carried south in the current. The Tasmanian waters are the nursery ground for this subspecies; there are no juveniles in New South Wales waters.

But in Tasmanian waters and in Bass Strait there are also large numbers of young of the western subspecies—possibly they predominate. As mentioned earlier, the two subspecies often occur in Tasmanian waters as mixed shoals—one or other subspecies predominating, or else the two occur about equally. There is a striking difference in the growth-rate shown by the two subspecies, even at this stage—the western subspecies appears to grow almost twice as fast as the eastern subspecies, in spite of the fact that the fish seem to be living under almost identical conditions. The difference in growth-rate is so marked that it may be possible later to distinguish between members of the two subspecies on this character alone, without reference to the gillrakers.

In Victorian waters the juveniles appear to be almost all members of the western subspecies.

Now the origin of these juveniles of the western species is obscure. They occur in fairly large numbers as mere fingerlings. They must, therefore, be spawned somewhere in the vicinity. The set of the currents in this region is to the east. By analogy with the situation in the east, it is tempting to suppose that these fry have been carried to the south and east from somewhere on the South Australian coast. Since there is no fishery for salmon along this part of the coast all this must be rather suppositional. But that is certainly what it looks like. There must be a large population of adults of the western subspecies somewhere on this part of the coast, to the west, to account for the large numbers of fry in Victorian waters and around Tasmania.

It appears therefore that when they reach maturity, or earlier, the mixed shoals of juveniles which occur round Tasmania split up into their respective subspecies, the members of the eastern subspecies moving to the north and east, and those of the western subspecies moving to the north and west.

In Western Australia the behaviour of the salmon is strikingly parallel to that of the eastern subspecies, as we know it in New South Wales and Tasmanian waters.

There is a winter fishery at Hopetoun and Esperance; only a few of the fish are taken west of Hopetoun. In summer, with developing roe, the fish make a westward movement and spawn in the Cape Leeuwin-Naturaliste area in April and May. Subsequently there follows a return movement of the fingerlings and first year fish. A few occur around the south-west, but the real concentration is in Esperance area and perhaps eastward of it. These movements are to be considered in connection with the current flow of this area.

Now what is particularly interesting is that half-grown salmon are almost unknown in Western Australia. Some shoals of three and four year old fish put in a brief appearance at Esperance in the summer. But they are never taken in any numbers around the south-west corner. It will be remembered that it was stated earlier that there was no fishing in all the area of the Great Australian Bight east of Esperance. It seems very likely that these juvenile salmon are distributed through the Bight, and perhaps even further east.

The similarity of the samples of two and three year old salmon from South Australia therefore becomes important. These two age-groups are commonly caught in the Gulfs of South Australia. That is highly suggestive. It seems that the salmon of this area (South Australia) are the juveniles of the stock of large, fast-grown salmon upon which the West Australian fishery is dependent; just as the stocks of salmon in Tasmanian waters include the juveniles upon which the fishery of New South Wales is dependent.

To what population then do the juveniles of the western subspecies, which are found in Victorian and Tasmanian waters, belong? They have no connection with the New South Wales fish. Where are the adults that give rise to them? They can hardly have been distributed from Western Australia.

There is, as a matter of fact, no record whence these juveniles can have come.

The South Australian-Victorian stretch of coast, as mentioned before, is known to be populated with salmon, but is virtually unfished. It seems that one must postulate at least one further population which spawns somewhere in this region, and whose fry are carried to the south-east, to be found later in Victorian and Tasmanian waters. A hypothetical boundary between this presumed population, and the supposed eastern limit of the south-west Australian population, has therefore been dotted in.

The extent of present ignorance about this population has been stressed, but the fact must not be lost sight of that there are these juvenile members of the western subspecies, occurring in very large numbers, in Victorian and Tasmanian onshore waters; and one must somehow account for them. Our present ignorance is due chiefly to the lack of observations along the South Australian-Victorian stretch of coastline.

This account completes the picture so far as it has been worked out. It can be described partly as well-established fact, partly as a working hypothesis, which will guide and direct future work. The limits of the stock on which the New South Wales fishery is based have been demarcated; and progress has been made in demarcating the limits of the stock of the south-western fishery.

There is just one further point. It may have occurred to some readers that the two subspecies would be better described as two, full, distinct species. There is a striking difference in the gillrakers, and probably in the rays of the dorsal fin.

No doubt these characters would be sufficient in some genera of fishes to create a new species. However, in the present case there is one other species of the genus *Arripis*—that is, *Arripis georgianus*, the Tommy Ruff (see Plate 2).

The Tommy Ruff is a considerably smaller species—the two have not been magnified to an equal degree in the plate. It will be seen that this species is morphologically very different from the salmon. The eye is larger, the snout is shorter, the caudal peduncle is narrower. Also the scale counts and fin-ray counts are very different from any of the populations of salmon.

All this is in contrast with the salmon—between the populations of which there is a high degree of uniformity in all but one or two characters.

If, therefore, one were to split the salmon—*Arripis trutta*, into a number of species, then the Tommy Ruff—*Arripis georgianus*, would have to be removed from the genus and a new genus created for it, which would then be a monotypic genus.

It seems best, then, all things considered, to leave the salmon as a single species, but to split it up into two subspecies, in each of which there is perhaps more than one population.

GIRTH SCALES

	26	27	28	29	30	31	32
Western Australia.			1	5	12	—	1
South Australia.			2	14	14	4	
South east Australia —western subspecies.			2	4	1		
—eastern subspecies.		1	10	31	5	2	
New Zealand.	1	9	16	8	1		
Lord Howe Island.		4	5	1			

DORSAL RAYS

	15	16	17	18
Western Australia.		15	55	21
South Australia.		7	20	8
South east Australia—western subspecies.			6	
—eastern subspecies.	2	22	13	1
New Zealand.	6	35	5	
Lord Howe Island.	2	8		

GILLRAKERS

	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
Western Australia.			10	52	28	21	3				1							
South Australia.		1	11	24	20	11	1											
South east Australia —western subspecies.		1	4	29	39	16	1											
—eastern subspecies.										1	11	50	62	77	25	—	2	
New Zealand.											1	5	22	13	6			
Lord Howe Island.													1	2	2	3	5	1

7

PACIFIC OCEANIC FISHERY INVESTIGATIONS
Statement of Program
by
O. E. Sette and M. B. Schaefer*

ABSTRACT

A brief statement is given of the equipment, methods, region of study and principal objectives of the Pacific Oceanic Fishery Investigations of the United States Fish and Wildlife Service.

The Pacific Oceanic Fishery Investigations with headquarters at Honolulu, T. H., is a division of the U.S. Fish and Wildlife Service engaged in the exploration and development of the high seas fishery resources of the mid-Pacific. Since the tunas constitute the group of pelagic fishes in this region having a large immediate economic potential, our efforts are being concentrated on elucidating the facts regarding the distribution, ecology and behavior of this group and developing means for their efficient and profitable capture.

For the sea-going phases of our work, we have three research vessels. The HUGH M. SMITH, an ex-Navy auxiliary, is a 128-foot ship outfitted to conduct oceanographical studies of all sorts as well as semi-commercial-scale tuna fishing by means of live bait, trolling, and long-line fishing. Conversion and outfitting of this vessel was completed in November 1949. After a shake-down cruise in Hawaiian waters, she departed in early January 1950 for an extended oceanographical and biological collecting cruise to equatorial waters which she successfully completed in early March. The HENRY O'MALLEY is a sister ship to the HUGH M. SMITH, but she is equipped for conducting live bait fishing, and trolling on a full commercial scale and for semi-commercial scale long-line fishing. She is also equipped for taking sub-surface temperature observations by means of the bathythermograph as well as with automatic surface temperature recording equipment. Her conversion and outfitting was completed in November and after a local shakedown cruise near Honolulu, she started in January on a cruise to the Line Islands region to explore the commercial tuna fishing potentialities of that area but was forced to return by an engine casualty which has not yet been rectified. The third vessel, the JOHN R. MANNING, is a newly-built 85-foot purse seiner especially designed and constructed for experimental and exploratory fishing by commercial scale purse seining. She is also equipped for trolling, for long line fishing and is capable of carrying live bait for possible employment in developing new techniques of seining, and like the O'MALLEY, has facilities for making surface and sub-surface temperature observations underway. This vessel has just recently been completed and is now completing a local shakedown and training period near Honolulu prior to departing for a voyage to the Line Islands region.

With these vessels for making observations at sea, the staff of 20 technical and scientific personnel (in addition to vessel crews and clerical people), are undertaking scientific investigations designed to furnish a scientific and practical basis for the development and management of the sub-tropical and tropical tuna fisheries of the mid-Pacific. Three major lines of investigation are being pursued: basic investigations of the biology, ecology and life history of the tunas, fishing exploration to determine variations in abundance and availability of tunas to conventional commercial gear, and experimental fishing to develop new forms of gear and new techniques of employing conventional gear.

The commercially most important tuna species occurring in the tropical and sub-tropical mid-Pacific region are the oceanic skipjack (*Katsuwonus pelamis*), the yellowfin tuna (*Neothunnus macropterus*), and the big-eyed tuna (*Parathunnus sibi*). The little tunny (*Euthynnus yaito*) and the frigate mackerels (*Auxis* sp.) occur only in the vicinity of land masses and are of minor importance commercially because they are not used for canning, which is the principal use of tuna by American enterprise. The albacore (*Thunnus germo*) occurs most abundantly in temperate waters, but is captured incidentally to other species by sub-surface gear in the tropics also. Bluefin tuna (*Thunnus thynnus*), another temperate zone species, is taken in the tropics even less frequently than the albacore. Our researches are, therefore, primarily directed to the study of the first three species named above, which are the only ones having a large commercial potential at this time.

* Prepared by O. E. Sette, Director, and M. B. Schaefer, Chief, Section of Research and Development, Pacific Oceanic Fishery Investigations, U.S. Fish & Wildlife Service, Honolulu.

BIOLOGICAL, ECOLOGICAL AND LIFE HISTORY STUDIES

Basic to the development of rational plans for the exploitation and management of the tuna resources of the mid-Pacific is the accumulation of the fundamental facts regarding the biology of the several tuna species, the conditions of the sea in which they live, and the relationships of the oceanic conditions to the life and behavior of the tunas and to the organisms upon which they feed.

Through accumulation and analysis of morphometric measurements made on tuna from different regions, to be supplemented later by tagging experiments, we are attempting to determine whether or not the population of each species in different regions of the Pacific are or are not independent of each other and, in the former case, the geographical limits of the several populations.

Since the tunas, being high-seas, pelagic fishes are oriented to conditions of the oceanic environment, we are attempting to learn how the variations in abundance and behavior of the tunas are related to the environment as a basis for devising improved fishing methods. The variation of potential productivity of different sea areas is also of importance for reaching conclusions as to which regions are capable of high sustained yields of tunas. To these ends we are conducting oceanographical surveys with the SMITH to correlate with the results of exploratory fishing by the other two vessels. Particularly important in this respect is the study of the equatorial and counter equatorial current system and the enrichment by upwellings associated therewith. Specific experiments to correlate occurrence of tunas with local variations in environmental conditions will be conducted by all three vessels.

Study of the age and rate of growth of the tunas, important to the problems of population dynamics of these species, is being undertaken by means of study of size frequencies and markings on scales and vertebrae. Preliminary results for the size frequency approach have been most illuminating and have indicated a rapid rate of growth of species studied. Study of scales and vertebrae seems to be less fruitful, but the subject has not been covered thoroughly as yet, and this deserves considerable attention since it is desirable, if possible, to devise methods of determining the age of individual fish.

The subject of maturation and spawning of tunas, important both with respect to seasonal variations in availability and with respect to the problems of population dynamics, has been until recently very obscure. We have good evidence that the yellowfin, big-eyed and skipjack all spawn near the Hawaiian Islands, as well as elsewhere, and we are planning to undertake research to learn something of the geographical, vertical and seasonal distribution of spawning in this region.

The primary fishing technique, both on the American West Coast and Hawaii, is by means of using live bait to chum-up fish to be captured by hook and line. Unfortunately, the small fish used for live bait are notedly scarce among the various islands of the mid-Pacific. It, therefore, is of importance to learn enough about their biology and behavior, and about those factors in their physiology related to holding and transporting them, to enable the most efficient use of the quantities available.

EXPERIMENTAL FISHING TO DEVELOP NEW GEAR AND NEW FISHING TECHNIQUES

Standard forms of gear (live bait, purse seines, long lines) in use in other regions may or may not be effective means of capturing tunas in the new regions which we are seeking to develop, and it is almost certain that even if they are effective to some degree, they may be improved in efficiency. The problem of improving gear of the several types and of devising new kinds of gear may be approached by applying various physical principles in the light of knowledge of the behavior of the fish and of the practical problems of shipboard operations, and involve both biological and engineering techniques. We shall seek through biological study of the reactions of tuna to various stimuli, both in captivity and at sea, to arrive at new ideas for the development of effective gear. Prior to the arrival of these results, however, there is a great deal to be accomplished in the way of learning the limitations of such conventional gear as the purse seine in this new region by trying it out on fish schools under actual operating conditions and so arrive empirically at ideas for improving gear and techniques.

It is expected that the knowledge of relation of distribution and behavior to environmental factors, mentioned earlier, will be also of value in the development of new gear and techniques of fishing. This should be particularly true of such sub-surface gear as long lines, the depths of fishing of which formerly have been arrived at on a purely trial and error basis.

There also appears to be room for much profitable development, by means of improved materials and mechanization, of already well known fishing methods. The tuna long line seems particularly likely to be made an effective and efficient gear by such an approach.

This gear is used in the Hawaiian Islands and in Japan. In the Hawaiian Islands a small boat carrying 4 or 5 men handle 20 or 30 "baskets"

of gear by hand or by the aid of primitive line pullers. Only the high price of fish, all of which go to the fresh market, makes this a profitable operation. Japanese vessels of large size employ line haulers of more advanced design, a single vessel handling up to 200 baskets; but crews of about 25 men are employed. The rates of production per man are such that they would not be profitable under American economic standards. At the same time, however, American fishermen, except in Hawaii, exploit only the young tunas which school at the surface and are passing up the opportunity to fish the older fish which live at deeper levels. It seems likely that rather simple applications of technological progress to the long line fishing method may make possible profitable American long line fisheries. An attack will be made on this problem the coming year.

EXPLORATORY FISHING TO DETERMINE GEOGRAPHICAL AND SEASONAL VARIATIONS IN ABUNDANCE AND AVAILABILITY OF TUNAS FOR LOCATING PROFITABLE FISHING AREAS.

As noted earlier, the tunas are not evenly distributed in the sea, but are concentrated in time and space in accordance with peculiarities of the oceanic environment and the seasonal cycles of their lives. The oceanographical variations are being measured as previously described and studies are being conducted of the life history and ecology of the tunas. Intimately related with these studies is the practical application of their results, charting by means of fishing on a commercial or semi-commercial scale the abundance of the fish and their availability to the fishermen.

This exploratory fishing must be conducted by standard gear calibrated in regions of known tuna abundance to be meaningful in a commercial sense. At present the only gear which we feel is sufficiently standard for this purpose is pole and line fishing, using live bait for chum. This will be the method first employed in our exploratory activities. The HENRY O'MALLEY and the HUGH M. SMITH will conduct live bait fishing this spring and summer in the vicinity of the Hawaiian Islands to give us a measurement of their effectiveness as compared with the local live bait fishing boats and crews. They will then conduct exploratory fishing in the Line Islands and Phoenix Islands regions.

Meanwhile, with the development of effective purse seining and long-lining techniques and gear, we hope to put ourselves in a position to standardize these forms of gear later and to employ them also in exploratory operations.

REGION OF STUDY

Although the area in which we are authorized to work extends from Hawaii to the Western Carolines and southward to Samoa, this is obviously too vast a region for us to study intensively at one time with the facilities available. We have, therefore, chosen to study first a region contiguous to the Hawaiian Islands because of the simplified logistics, because of the fact that tunas are known to occur throughout the region in some quantity, and because it is logical for a commercial fishery to expand from its present location to the nearest adjacent profitable fishing area. The region in which we propose to work initially reaches from Midway to the Phoenix Islands and from Hawaii to Malden Island. While this is less than one third of our authorized area, it is as large as we can handle at once. Indeed, perhaps it is a bit too large. Probably several years will be required to explore this area thoroughly, after which we will work further westward.

In this region, the University of Hawaii and the Territorial Division of Fish and Game of Hawaii are also studying local tuna and bait fishery problems. The programs of the three organizations are mutually supplementary and some phases are being undertaken jointly.

8

MARINE FISHERIES OF PAKISTAN WITH A REVIEW ON TRAWLING

by

M. RAHIMULLAH (Qureshi)*

ABSTRACT.

A brief account is given of the main features (gear, species etc.) of the marine fisheries of West Pakistan. The results of the trawling trials in these waters are discussed and suggestions are made for future work in developing these fisheries.

The coast of Pakistan consists of two separate divisions, viz., of Western Pakistan and the Eastern Pakistan. Again the Western Division is divided into two sub-divisions which are more or less distinct from each other: the Sind and the Baluchistan coasts.

Sind coast consists of a large number of creeks which extend to a considerable distance inland, these creeks form a network starting from Karachi to the Sir creek. These creeks are the old mouths of the rivers, formed by the changing course of the rivers from time to time. The coast line is about 180 miles in length and borders the Indus plain; hills are noticeably absent in this region. It is fed by the river Indus and the marine fauna on this coast is quite rich. The 100 fathom line lies more than 80 miles away from the gradual sloping coast line interrupted by a swatch opposite the delta of the Indus.

Baluchistan or Makran coast consists mainly of bays with a few back waters, one of which is Sonmiani Hor situated about 65 miles north-west of Karachi and the other is Kalmat Khor another 100 miles further west. The principal habitations of the fishermen are Damb Bunder, Sonmiani, Pasni, Gwadar, Ganz and Jivani on a 350 miles long coast which is fringed with barren hills, some of which rise to about 2,000 ft. The 100 fathom line lies very close to the coast, being about 25 miles away, there is an abrupt drop reaching to a depth of more than 1,000 fathoms.

The coast of Eastern Pakistan is formed mostly by the mouths of the Ganges and the Brahmaputra and then is extended south, pierced at places by the mouths of other rivers. The coast line is about 200 miles long—the 100 fathom line is quite far off, the continental shelf slopes gradually and the sea floor is muddy and covered by terriginous ooze. It is also traversed by a swatch opposite Ganges mouth; otherwise it is much shallower than the coasts of western Pakistan.

FISH STOCKS

The fish stocks consist of:

Herrings. Shoals have never been observed of sardines, but this may have been due to lack of observation units. *Hilsa ilisha*, known as 'Hilsa' in the East and 'Palla' in the west Pakistan, is caught in large numbers on both sides when it ascends the rivers for breeding. *Clupea toli* is also quite abundant in the Arabian sea and is caught in fairly large numbers during the months of March to June and in lesser quantity during other fishing months. Smaller species are also available inside the creeks and on the shallow margins.

Cat-fishes are abundantly caught during the fishing season which lasts for about 9 months, June to August being monsoon period when no fishing in the sea is possible by the local fishermen. These fish rank low as food and most of the catch is cured and exported.

Amongst the *percomorphs*, the perches, snappers and sea-breams with horse-mackerels constitute the major part of the catch. The drums or Croakers are caught in shoals during the months of October to December and again in February and March, at other time of the year a few are caught by the trawler but the local fishermen do not get it. It seems that these fish come near the surface when they are shoaling. There are records of catches up to 30,000 at a time, and 6,000 to 10,000 is quite common. The catch consists mostly of *Sciaena diacanthus* (Sua or Ghol) and *Sciaena sina* (Sueeri), the weight of these fishes ranges between 16 lbs to 30 lbs. *Polynemus* or Thread-fins are also available in large numbers near the mouths of the Indus from February to April. Pomfrets are caught throughout the fishing season, they are quite abundant during the cold season, they are usually caught in shoals of 100 or more. Tuna fishing is poor and shoals have never been observed. These fish are caught on single lines and also netted. Mullets are abundant on the shallow margins and in the creeks.

*Director of Fisheries, Sind Department of Fisheries, Karachi, Pakistan.

Flat-fishes, soles and the tongue-soles are caught in plenty by the trawler and in lesser numbers by the fishermen. These are consumed only in good hotels and are not much esteemed by the local people. Amongst the flat-heads, *Batrachus* and *Platycephalus* are caught only occasionally.

Sharks, skates, saw-fishes and the hammerheaded sharks are represented by many species. These are not consumed locally and are cured and exported. There is no shark liver-oil factory in West Pakistan but the oil is extracted departmentally on a small scale and supplied o the veterinary and other departments in East Pakistan. Rays are represented by 15 species, the Eagle-rays are quite common and occasionally are seen jumping out of water. The rays also fall in the category of sharks and are not consumed locally, being cured and exported.

Rhineodon or the Whale-shark is a seasonal visitor to our coast. Three specimens, two males and one female, 21 ft. 41½ ft. and 38 ft. respectively were caught in October 1949 by the local fishermen. The oil extracted from the livers and tested in the laboratory showed very little trace of vitamin A.

Prawns are caught in fairly large numbers, a little quantity used fresh and the rest cured and exported to Ceylon and Burma. This commodity, if properly handled with the latest methods of preservation, can be a very good asset. Other marine animals are edible oysters, pearl oysters (*Placuna*) and sponges, but the commercial value and utility has not yet been determined.

The total production of marine fish in Pakistan is 40,000 tons, about two-thirds is produced in the West and the rest in the East. Of the total catch more than 60% is cured and exported. The methods of preservation are crude and primitive; near Karachi and on the coast of Sind, coloured salt is issued to the fishermen for this purpose hence the quality is poor. Salt is available in natural condition on the Makran coast.

There are different types of country craft (sailing boats varying in tonnage from ½ to 30 tons). These are of 5 types on the Sind and of only one type on the Makran coast. The smaller boats go out to the sea for about 24 to 30 hours but the bigger ones remain out 4 to 6 days at a stretch, these carry wooden boxes in which ice is taken for the preservation of the fish; big fish are salted and kept in a separate hold. The total number of boats is 10,200. No power fishing is done privately.

The nets range from cast nets to drag nets and stake nets; bag nets are used only in the Karachi harbour, by a section of fishermen, otherwise these are not common in the West; bag nets are extensively operated in East Pakistan. In the open sea driftnets are in general use adjusted to the habits of the fish; they are marked by two buoys, but the greatest drawback is that no lights are put up at night with the result that some nets have been damaged by the trawler. Long lines are also in use but by only few fishermen, single lines are quite common.

The population of fishermen is about 120,000 of whom one-third may be taken as actually engaged in fishing. The women also take part in the industry; they twine the yarn in the houses but do not sell fish in the markets. The fishermen have their own villages and do not like to live in the city even if given the opportunity to do so. They are strong, sturdy, honest but illiterate and superstitious. There is good scope for socio-economic work amongst them and great possibility of organising them into corporate bodies.

Shore installations are very unsatisfactory, there is only one cold-storage at Karachi at present but that too is not exclusively for fish. Arrangements are being made to instal fairly big cold storage plants in both regions of Pakistan and the construction of ice factories is also under consideration by the Government. The introduction of carrier launches with refrigerated hold is also proposed for bringing in fresh fish from far off places.

TRAWLING

Trawling—although the Government has two fishing vessels, only the trawler ALA has made some fishing trips, the other vessel is not ready for operations. ALA was purchased in England and brought to Karachi in October 1947. She has a length of 80 ft., gross tonnage 81.24, steel hull with a diesel Ruston Engine of 150 B.H.P. She has a refrigerated hold to carry 30 tons of fish but at present is not in a working condition owing to a faulty compressor cylinder. Since her arrival, she has made more than 15 trips. The fishing operations have been carried out within a zone of depth from 10 to 20 fathoms. The operations confirm the evidence of the charts relating to the ubiquity of mud bottom; some hauls were made beyond Cape Monze lately indicating the rocky bottom and the presence of corals.

The fishing operations have yielded approximately 90 lbs. of fish per hour of fishing which means 1,500 lbs. (about 13 cwt.) per day's absence. The stock is identical with the catch of the local fishermen and is composed more or less of the same types as reported by other trawlers which have operated and are operating on the coasts of Bharat. The results on the whole are not very encouraging

but considering the short period of trial it would be hasty to infer anything definite.

There are no shore installations near the harbour for the preservation of the fish, no curing yard is in existence, markets are also in an unorganised condition, the result being that the fish has to be disposed off within two days at the most and consequently very low price. The other factor is the proportion of non-edible fish, i.e., sharks, skates, rays, etc., which is sometimes as high as 40%; these give very little return and if nothing is done to gain more from these varieties, the trawling in tropical waters is bound to be handicapped to a great extent.

Trawling has been tried in the Bay of Bengal by "GOLDEN CROWN" in 1908-09, by "VIOLET" and "MARGARITA" in 1907 and 1908 in Ceylon and Madras waters, by "LADY GOSCHEN" on the Bombay and Sind coasts in 1921-22 and recently by "MEENA" off the Bombay coast. The results of these trials are published and I need not go into details here.

Now, I will try to answer some of the questions raised by Dr. G. L. Kesteven in a recent report on the 'Fisheries of Pakistan' in connection with the working of ALA. "The question then arises whether these results are attributable to the vessel, her crew, to the fish stock, or to the market."

To take the vessel first: it is old and a lot of time is wasted on its repairs, involving heavy expenditure. It is small and the present operations are confined at the most to 6 days, the average trip is usually of 4 days' duration, thus it remains in the port for an undue proportion of time. It can not fish in squally weather or during the monsoon, and thus loses another 4½ to 5 months in the year on this account. Whether trawling would be possible during the monsoon is a problem to be solved by a gear specialist and that too after some trials.

ALA carries a crew of 14 which is rather excessive for a vessel of this size: no commercial concern would keep more than 10 or 11. The Skipper has been recruited from England because nobody in this country was available who could handle this gear, the salary and allowances paid to the skipper are fairly high and may be cut down if the crew working with him can take over the trawling operations.

Fish stock is also a factor which requires serious consideration and careful analysis. The proportion composition of the edible to non-edible fish is normally in the ratio of 70:30 and unless more can be gained from the latter, income is bound to be less. The present price of edible fish also is low and it is essential to get better prices to make the scheme more remunerative. There should be proper arrangements for preservation and the fish should be sold in such quantities as not to lower the market price. Marketing also must be organised on a proper basis because the conditions prevailing at present are far from satisfactory.

Now, taking as a whole, I may point out some features of trawling in the past and the present in our waters:

1. In every case old vessels were purchased and much money was spent on reconditioning and overhauling; maintenance cost was also very high.

2. These vessels were selected probably by those who had no idea of fishing in tropical waters and who did not think at the time of selection whether these vessels would be suitable to the waters in which they would operate.

3. Trawling was tried in two or three places and the experience thus gained should have been a good indication for avoiding the same mistakes; some other methods should have been tried instead, viz., catching the surface and mid-water fishes.

4. Operations were started without giving any serious consideration to the markets, marketing and the shore installations.

In the end I may say that the success of trawling is very doubtful in tropical waters owing to the stock of demersal fish and it should be worthwhile to try craft and gear which may give us more fish from surface and mid-water as these are the chief marketable fish.

Yet another suggestion, the adjacent countries like Bharat and Pakistan, Burma and Indonesia, etc., should co-operate and should not duplicate the investigations and research problems. By this I mean that if a country is trying trawling the adjacent one should try other methods and compare the results at the annual meeting of the I.P.F.C. or the officers of these countries should meet occasionally for consultation and to thrash out their common problems. In this way great economy can be achieved and better results obtained by the member countries of this organisation.

BIBLIOGRAPHY.

AMIRTHALINGAM, C., (1948).—The Wealth of Ceylon Waters. Ceylon Assoc., Proc.,

————————, (1949).—Report on trawling in Ceylon Waters (*in MS.*)

HARDENBERG, J. D. F., (1949).—Development of Pelagic Fisheries. I.P.F.C., *Proc.*

HORNELL, J., (1914).—Notes upon two exploring cruises in search of Trawl Grounds off the Indian and Ceylon coasts. Madras Fish. Bull., 8: 23-41.

KESTEVEN, G. L., (1948).—Report on the Fisheries of Pakistan, India & Ceylon Mimeo.

————————, (1948).—Fisheries of south-east Asia. Mimeo.

————————, (1950).—Fisheries of Pakistan.

RAHIMULLAH (Qureshi), M., (1948).—Fish and Fisheries of Sind and Karachi (Marine). *Sind Inf.*, 1(18): 363-366,

——————, (1948-49).—Departmental Reports on Marine Fisheries (in MS.).
——————, (1949).—Fisheries survey of the Baluchistan Coast (in MS.).
——————, (1949).—Prawn Fisheries of Sind. *Sind Inf.*, 2(8): 173-174.
——————, (1949).—Marine Fisheries of West Pakistan. (in MS.).
——————, (1949).—Marine Fishes of Karachi and the coasts of Sind & Maran. (in MS.).
——————, (1949).—Fishing along the West Pakistan coast, *Pakistan*, 1(3): 50-54.
RAO, H. S., & Panikkar, N. K., (1949).—A survey of the pelagic fisheries of the World. I.P.F.C., *Proc.*:
SEWELL, R. B. S., (1946).—Memorandum on the proposed Fishery Research Institute for India.
SORLEY, H. T., (1932).—Marine Fisheries of Bombay Presidency.
THOMPSON, H., (1949).—22 p.c. increase in World catch probable. *Fish. Newsletter.*

9

REPORT ON NON-INDIGENEOUS FISHING GEAR RESULT OF THE FIRST SERIES OF EXPERIMENT ON THE OPERATION OF "MASU AMI" (A COMMON JAPANESE TRAP NET) IN THAI WATERS**

by
Swarng Charernphol*
and
Tuanthai Bamrajarinpai*

Abstract

Trials in the use of the Japanese Masu in Thai waters are described. It is suggested that the results, which compare favourably with the results of operation in the same waters of the local gear, Poh, of similar construction and purpose, warrant the conclusion that this gear may, with modifications in construction and operation, be used as a replacement for the Poh.

Among the numerous types of fishing gear operating along the coasts of Thailand the Poh (Bamboo stake trap) is the most important since about 70% of the total catch of sea fish is taken with this gear. Poh fishing has been practised in this country for several centuries, yet, the Poh of today remains practically the same in constructional details and in methods of operation as that of the old days, without any appreciable improvement. Poh fishing flourished in the past when living standards were low, labour cheap and material plentiful. At present, however, price of material and costs of labour have increased greatly and in following traditional methods of operation those who practise Poh fishing suffer great loss. If the present conditions remained unchanged Poh fishing would decline rapidly and the annual production of fish would greatly decrease. Furthermore, since as many as 250 wooden poles and 10,000 bamboo poles are required for the construction of a fair sized stake and assuming that there are 1,000 stakes in existence, the requirement of good sized log and bamboo poles (25,000 of the former and 10,000,000 of the latter) constitutes a considerable drain on the national forestry resources. This also would suggest that the future of Poh fishing is threatened.

The Department of Fisheries is seeking a solution to the problem from two different directions; first, by experiment on the improvement of the design, construction and operation of the existing Poh, and second by experiment on some non-indigeneous gear to find the type or types that may be used in Thailand to replace the Poh with advantage. This present paper describes work along the second line, using a Japanese type of trap net.

The results of the first series of experiments on the operation of this gear in Thai waters, with notes regarding its efficiency and cost of operation in comparison with those of Poh under the same environmental conditions are given.

MASU AMI (Figs. 5, 6, 7, 8)

This gear, because of its low capital investment, low operational cost and easy operation, is very popular in Japan, preferred especially by those fishermen who have only small capital. The Masu Ami trap consists of a wing and a net which has several pockets (the one used for these experiments has 8 pockets).

* Department of Fisheries, Bangkok, Thailand.
** The writers wish to express their gratitude and thanks to Dr. S. W. Ling, Assistant Regional Fisheries Officer of the F.A.O., Regional Office for Asia & the Far East, for advice and assistance in preparing the report.

The net is about 115 meters long and 15 meters deep with 3 cm, mesh made of cotton twine, provided with lead sinkers and bamboo floats. Raw cotton rope and cocoanut fibre rope are used as head rope and ground ropes respectively.

The wing is 72 meters long and 12-13.5 meters deep; it is made from several units of cotton netting with different meshes. Head rope, ground rope, floats and sinkers used on the wing are the same as those of the net proper.

The bags are attached to the middle side of the net, 6 to 8 in number, designed on the fyke net principle. Each bag is cylindrical, measures 8.75 meters in length and is made of three sections each of its own mesh size. The shape of the bag is maintained by three rattan rings, one at the entrance and one between the junction of two sections. The rattan rings used are 1.9 1.5 and 0.9 meters in diameter respectively. The catch can be removed at any time through the distal end of the bags.

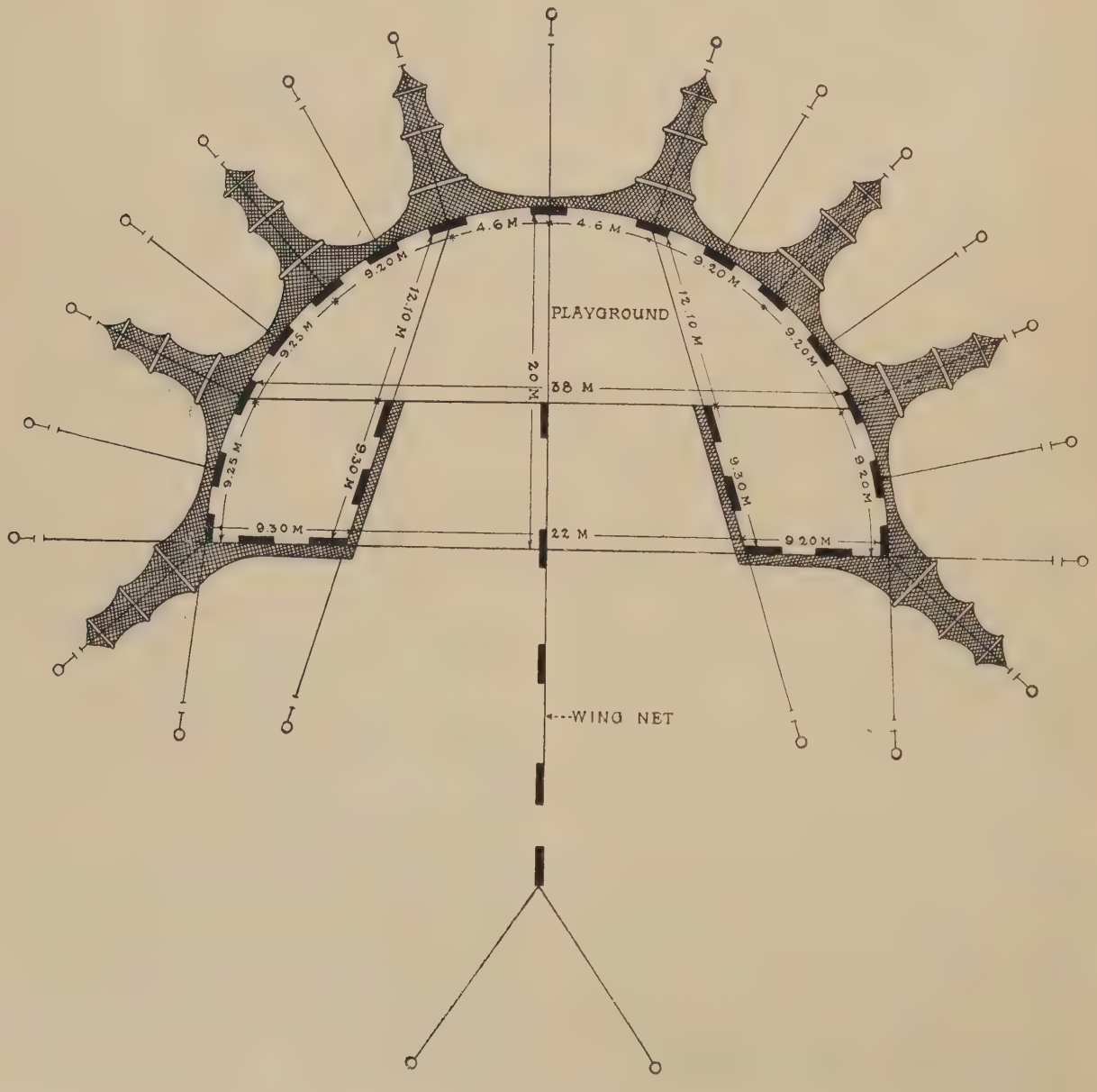


FIG. 5

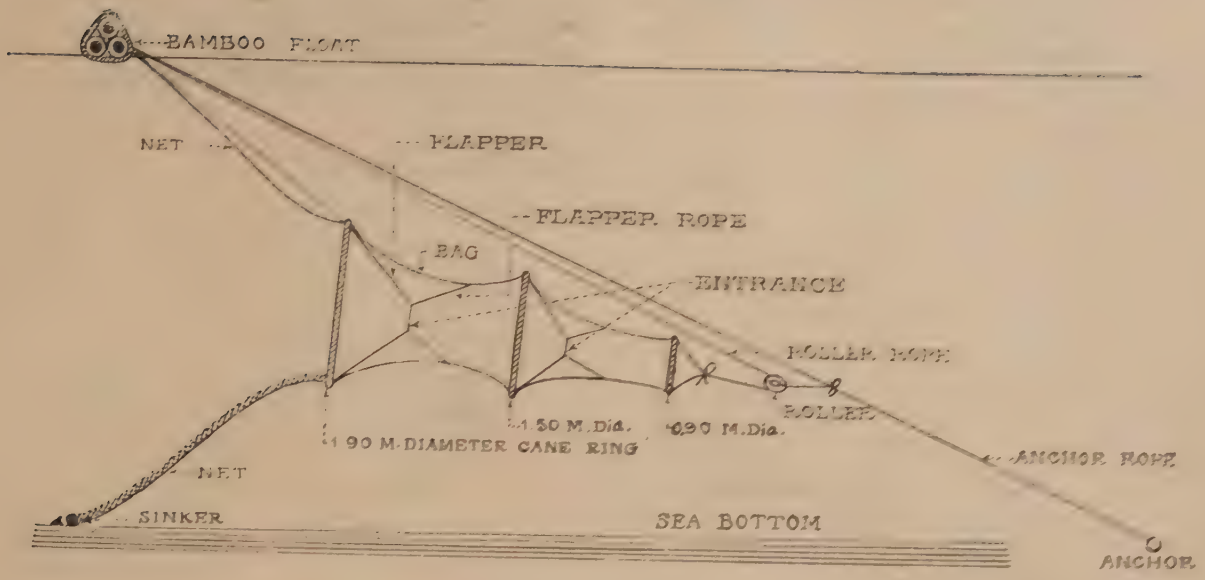


FIG. 6

DIAGRAM OF PLAYGROUND NET

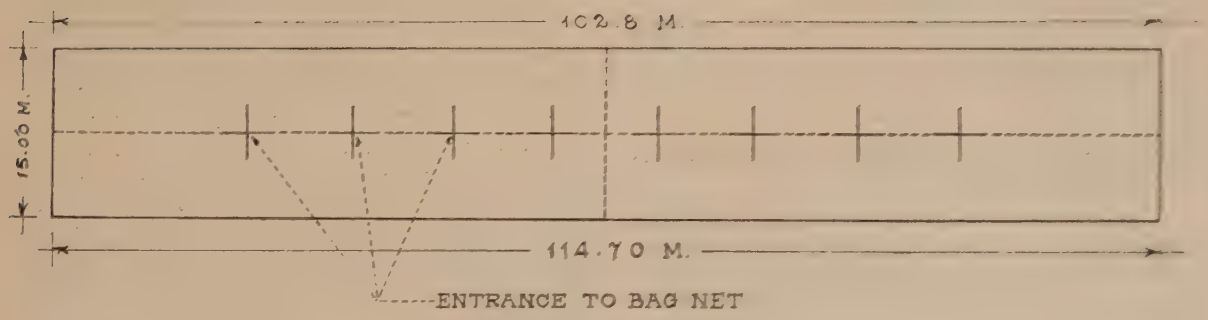


FIG. 7

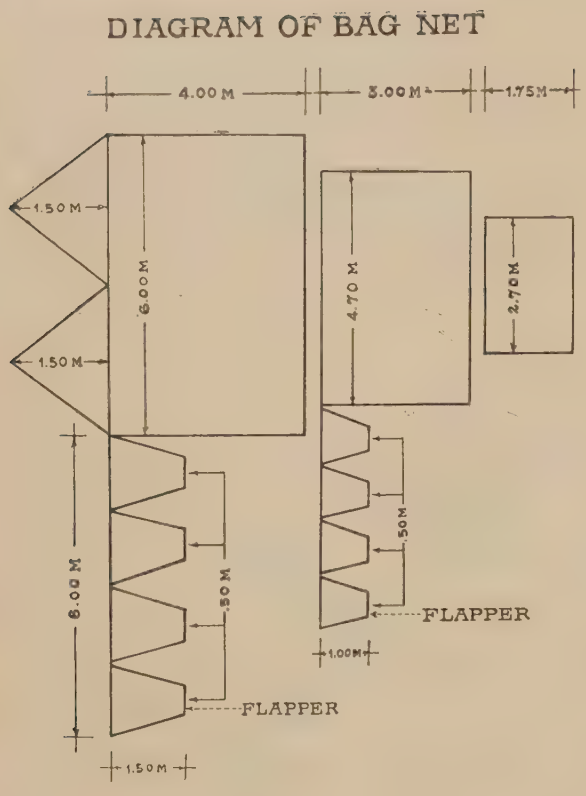


FIG. 8

In setting the trap (Figs. 1 to 4) one sampan and 5 to 6 persons are required. Traps may be set in a depth of 5-50 meters with preferably muddy bottom. When the bottom is sandy, heavier anchors should be used. It is difficult if not impossible to set Masu Ami on rocky bottom.

In setting the net the ropes, anchors and floats are laid down first to form the framework, then the wing, net and bags are set in position and tied to the framework.

EXPERIMENT ON FISHING OPERATION MASU AMI

The principal objectives in carrying out these experiments were to determine the efficiency and economy of Masu Ami in comparison with the local Poh operating under similar conditions, and to ascertain whether it would be desirable to introduce this gear to replace the Poh.

Prior to the first actual net setting much time was spent in preparing the parts of the trap and accessories and in practising technique of trap setting.

During the first trial the Japanese method of operation was followed, subsequently certain modifications were made to suit the local conditions.

Sites selected for the trap were locations where Poh stakes were operating nearby, but with no interference with each other's fishing activities.

So far only three experiments have been performed. Further experiments are now being planned and will be carried out in the Bay of Ban Pae, which is calm and well protected during the coming S.W. monsoon season.

First Experiment

Locality — Ket Point, about 2.5 miles South-west of Pae village.

Date — 7 November to 20 November, 1949.

Conditions of the Site:

Depth of water — 11.5 meters.

Bottom — sandy with little mud.

Current — strong, uneven and with different speed between the top and middle waters.

Actual fishing days — 2.

The first week, 7th to 14th November, was spent entirely on preparation and getting material ready.

The actual work on trap setting started on the 15th November. One whole day was spent in setting the framework with ropes, anchors and floats.

The work on setting the net and wing was completed during the second day, 16th November.

Because the bottom was sandy and the current strong the anchor ropes began showing signs of loosening in the very next day after the trap was set, and the shape of the trap became distorted.

On 20th November, the condition of the trap was very poor. Some of the anchors became loose and entangled with the net. The catch was taken out and the trap dismantled and removed. A large amount of sea-weed and other floating material was caught in the net, making it very heavy and difficult to operate. The net was broken in several places, believed to be damage caused by sharks.

The catch from this experiment was poor and consisted mostly of barracuda, rays, squids, and dorab; many of the surface feeders were found dead gilled in the mesh.

The poor result of this experiment was attributed to:

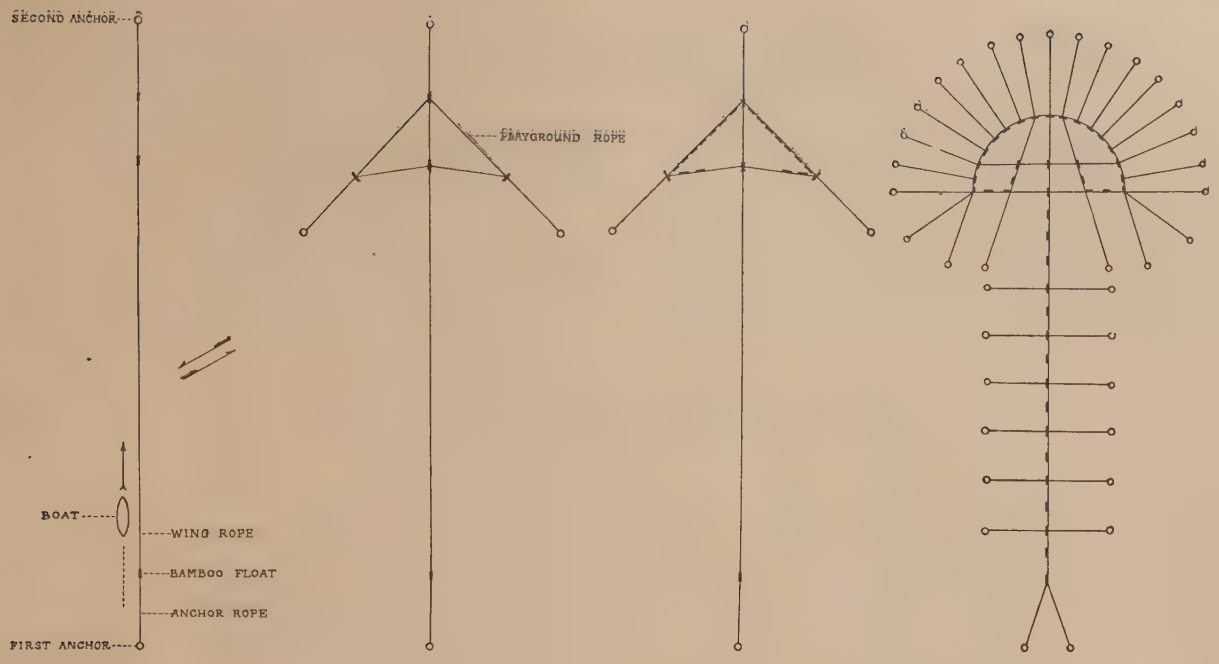


FIG. 1 FIG. 2 FIG. 3 FIG. 4

FIGURES 1 to 4, showing the stages in setting the net.

1. Strong current and sandy bottom; anchors used were not strong enough to hold the trap firmly, net became entangled and bags twisted, preventing fish from entering.
2. Ground ropes not fixed properly, bottom part of net became loose, allowing fish to escape.
3. Upper edge of net and bags were dragged too far down below the water surface due to insufficiency in the number of floats used as related to the strong current.

Experience from this experiment prompted the suggestion that to have the trap set firmly and functioning properly on sandy bottom with strong current, stronger anchors were required, with longer anchor lines and more floats and to avoid fish being gilled on the net, the mouth of bags should be set higher up toward the surface of water—about 3/7 of the depth of water instead of the customary height which is half way between surface and bottom.

Record of Catch—1st Experiment

DATE	CATCH (IN KGS.)						REMARKS
	Barracuda	Squid	Ray	Dorab	Miscellaneous	Total	
18th Nov. 49	6.5	6.0	1.0	1.0	10.5	25.0	due to poor condition of the net the catch was smaller than expected.
19th „ 49	4.0	5.0	3.0	1.0	2.4	15.4	
	10.5	11.0	4.0	2.0	12.9	40.4	

Second Experiment

Locality — Koh Samet, about 6 miles South-east of Ban Pae

Date — 6th to 23rd December, 1949.

Conditions of the Site:

Depth — 10.2 meters.

Bottom — Mud.
Current — Moderate, about ½ mile per hour.
Range of Tide — 2 meters.
Actual fishing days — 15.

The framework of the trap was completely set during the first day, 6th November, and the entire trap was set up during the second day. Thirteen long wooden poles were used to strengthen the framework of the trap in addition to the usual number of anchors.

The wing net was hauled up once in every two days for inspection and for removal of undesirable substance caught on it. The fish gilled on the net were also removed to prevent sharks damaging the net. By doing so the condition of the net was well maintained. The size of fish gilled and their position of the net were careful recorded.

The net was lifted on December 23rd, and it was found to be in good condition with only some small sections of it slightly torn.

The kind and quality of fish caught are shown in the following table:

Record of Catch—2nd Experiment

DATE	CATCH (IN KGS.)					
	Lactarius	Dorab	Gizzard Shads	Shark	Misc.	Total
9th Dec. 49	1.2	17.0	—	—	14.35	32.55
10th „ „	1.0	31.0	—	4.5	25.30	61.80
11th „ „	6.45	19.15	—	9.5	19.36	54.46
12th „ „	11.4	3.0	—	5.75	25.70	45.85
13th „ „	13.7	12.25	—	1.30	19.15	46.40
14th „ „	2.25	3.15	—	0.70	8.0	14.10
15th „ „	6.25	4.25	—	7.15	21.58	39.23
16th „ „	20.0	2.25	141.50	0.80	17.91	182.46
17th „ „	17.5	11.60	—	8.0	23.15	60.25
18th „ „	15.5	19.50	—	2.10	21.70	58.80
19th „ „	67.5	19.50	—	—	20.67	107.67
20th „ „	162.65	24.0	—	2.60	10.55	199.80
21st „ „	76.5	1.95	—	1.10	15.95	95.50
22nd „ „	54.1	—	—	—	14.75	68.85
23rd „ „	29.0	1.10	—	—	8.45	38.55
Total	485.00	169.70	141.50	43.50	256.67	1106.27

For 15 fishing days the total catch was 1106 kilos, thus the average catch per day was 73.7 kilograms. During the same period the average catch per Poh per day, for Poh stakes operating nearby, under the same conditions, was about 50 kilograms.

Third Experiment

Locality — Same as 2nd Experiment.
Date — 7th to 25 January, 1950.
Condition of Site:
Depth — 11 meters.
Bottom — Mud.
Current — Moderate.
Actual fishing days — 17.

Prior to the experiment the net was treated with a lukewarm solution of coal tar and creosote mixture (10% creosote in coal tar). The local fishermen were not familiar with this method of net preservation and were afraid that the colour and order of the preservative might repel the fish. However, the results of this experiment indicated that fish were not repelled by this net preservative.

The site selected for erection of the trap for this experiment was about 100 meters east of the site used for the previous experiment.

The framework of the trap was laid down on 7th January, and the whole trap with netting was completely set on the next day, January 8th.

The wing used for this experiment was 150 meters in length, twice as long as those used for the previous experiments. The increase of the length of the wing showed definite increase in catch.

The types and quantity of catch are shown in the following table:

Record of Catch—3rd Experiment

DATE	CATCH (IN KGS.)					
	Scom-beroides	Rastrel-liger	Eleuthe-ronema	Poma-dasys	Miscel-laneous	Total
9th Jan 50	1.35	—	2.50	0.50	20.80	25.15
10th „ „	—	0.75	16.00	—	56.10	72.85
11th „ „	—	159.55	16.50	—	45.95	222.00
12th „ „	0.90	0.90	7.20	—	41.10	50.10
13th „ „	—	—	7.50	—	8.70	16.20
14th „ „	—	—	—	—	11.70	11.70
15th „ „	—	31.50	2.00	—	20.75	54.25
16th „ „	0.80	3.00	4.75	—	25.35	33.90
17th „ „	287.00	—	—	—	16.90	303.90
18th „ „	273.00	—	—	25.00	11.05	309.05
19th „ „	181.00	—	—	10.00	14.00	205.00
20th Jan. 50	149.00	—	—	—	10.00	159.00
21st „ „	21.00	—	—	—	8.20	29.20
22nd „ „	282.00	—	—	—	11.00	293.00
23rd „ „	15.00	—	—	—	16.00	31.00
24th „ „	9.00	—	—	—	2.00	11.00
25th „ „	208.00	—	—	—	13.00	222.00
Total	1426.70	197.05	56.45	35.50	332.60	2048.30

For 17 fishing days the total catch was 2048 kilos, giving an average catch per day of 120 kilograms. During the same period the average catch per day for each Poh operating nearby under the same conditions, was only about 30 kilos.

It may not be out of place to mention here that in Japan during the peak of the fishing season a catch of 3 tons per day per Masu Ami is not uncommon. Since the fish stock of the inshore waters of Thailand is far richer than that of Japan it is not unreasonable to expect a daily catch of over 4 tons per Masu Ami operating in waters during good fishing season.

DISCUSSION OF RESULTS

These experiments represent the first series of trials on the operation of Masu Ami in this part of the world. Although the season when the experiments were conducted was a poor one for trap fishing and the catch obtained was nothing exciting, yet the results are of considerable significance.

These experiments indicate clearly that the Masu Ami, which is intended for fishing in calm and well protected coastal waters, requires some modification before it can be adopted to operate in localities where current is strong and bottom sandy. With stronger anchors, possibly assisted by a few long wooden poles the net could be set firmly even where the bottom is sandy and current strong. With more effective floats, such as those of glass, to replace the bamboo ones, the net with its bags could be held in good position for the fish to enter.

The length and mesh of the wing require some change. By lengthening the wing, more fish could be intercepted and directed into the net. The mesh should be changed in accordance with the size of local fish.

The amount of dead fish may possibly be reduced by removing the catch from the bag at shorter intervals.

Net preservation is important in Masu Ami fishing. More detailed studies on the types of preservative and technique for their application are required.

Further experiments are required for improvement of the design of the trap and technique of its operation in Thai waters before introducing it to the local fishermen.

The amount of capital investment and operational expenditures of Masu Ami and Poh and a summary comparison regarding the advantages and disadvantages between the two kinds of traps are given below:

CAPITAL COST & OPERATIONAL EXPENSES

Masu Ami

Capital Investment

27,470 Baht

One set of net	20,000	Baht
Sinkers	1,620	„
Ropes	4,000	„
Anchors	1,650	„
Bamboo and Rattan	200	„

Expenses of Trap setting

760 Baht

Rent for small boats	60	Baht
Wages for crew	175	„
Wages for labours	525	„

Monthly Operational Expenditure 2,750 Baht

Rent for fishing boat	400	Baht
Rent for Sampan	200	„
Wages for Captain	750	„
Wages for fishermen	900	„
Net preservation & Miscellaneous	500	„

Poh—Medium size, set in a depth of 11 meters.

Capital Investment

29,125 Baht

Wood poles, Bamboo & Rattan	19,700	Baht
Wire, rope & nails	4,225	„
Miscellaneous? Auxiliary?	5,200	„

Expenses of Trap Construction

6,475 Baht

Rent for sailing boat	600	Baht
Labour for making Bamboo screens	375	„
Labour for setting framework	4,500	„
Labour for setting Bamboo screens	1,000	„

Monthly Operational Expenditure

3,600 Baht

Rent for sailing boat	400	Baht
Wages for Captain	750	„
Wages for 5 fishermen	2,250	„
Net preservation & miscellaneous	200	„

Comparison between Masu Ami and Poh

	Masu Ami	Poh
Capital investment	Less	More
Monthly Operational Expenses	Less	More
Trap setting and operation	Easy	Complicated
Nature of gear	May be dismantled and re-set	Unmovable
Persons required for operation	2—3	6—7
Wood poles required	few or none	Many
Catch efficiency	More species and larger quantity, no fish can escape	Less species and small quantity, some fish may escape
Durability of gear	2 years	only 1 year
Condition of fish caught	some may be dead inside the net	no dead fish
Time for removing catch	Any time	only ebb tide
Preservation & Care	Net requires monthly treatment	Unnecessary

CONCLUSION

1. Masu Ami when set strictly according to the Japanese method could not stand firmly against the strong current of local waters.

2. When a few wooden poles were employed to support the framework and heavier anchors used the trap was strong enough to resist strong current.

3. By increasing the length of the wing more fish were intercepted and directed into the net.

4. Net treated with creosete—coal tar mixture did not show repelling effect on fish.

5. The capital cost and monthly operational expenditure of a Masu Ami are less than those of a Poh of corresponding size.

6. Masu Ami is easier to operate and requires less personnel than Poh.

7. It takes only two days to set up a Masu Ami, and less than one day is enough to dismantle it.

8. The catch of Masu Ami consisted of more species and larger quantity than the catch of a corresponding Poh operating under similar conditions, but some of the fish caught died inside the bag.

9. Masu Ami fishing requires very little or no wooden poles.

10. Masu Ami with certain minor modifications can be operated in Thai waters with good results and may be introduced to replace Poh with advantages.

10

INDIGENOUS MARINE FISHING GEAR OF THAILAND*

by

Swarng Charernphol**

Abstract

Fifty-four different types of fishing gear used in Thai waters are described. The construction, mode of operation, craft, catch, and localities in which used are given for each, with notes on preservation, cost and distribution of earnings where the latter information is available. The catalogue constitutes a representative assemblage of Thai fishing gear.

Introduction

Thailand, extending from 5°N to 21°N and from 97°E to 106°E, is a tropical country, with typical tropical fauna and flora. The Thailand part of the Gulf has a coast line of approximately 1,000 miles with approximately 65,000 square miles of fishable waters. The water of this area is rather shallow, roughly with an average depth of 20 meters for the inner Gulf and 35 meters for the out Gulf. The bottom slope is gentle, being about 0.3 to 0 6 meters per mile. The bottom is predominantly muddy at the margin and changing gradually becomees sandy towards the deeper part, whilst rock and coral patches occur everywhere. The run-off of freshwater into the Gulf is tremendous, thus converting huge regions close to the coast into brackish water areas and mangrove stands.

The Thai coast on the Indian Ocean side is about 300 miles long, a typical oceanic coastline, with exposed sandy beaches, rocky foreshore and sheltered bays.

The aquatic resources of the Thai waters are rich in quantity and variety. 'Pla thu' (*Rastrelliger spp.*) herrings (*Clupea sp.*) Dussumieria, Engraulis, mullets, threadfins, catfishes, rays, shrimps, Mytilus etc. are caught in large quantities in waters of low salinity. Barracudas, groupers, snappers, breams etc. are important species, of waters of deeper regions. Mackerels, Caranx, shark etc. occur also in large numbers in deep as well as onshore waters.

There is practically no cultural operation along the coast except in few localities where small amounts of mullets and sea-bass are cultivated. The main fishing industry depends on capture operations.

Because of the physiographic conditions of the coastal waters and the habit and tradition of the fishermen, fishing operations are generally confined to near-shore waters of less than 30 meters deep and less than 10 miles from shore.

There are great varieties of fishing gear in the various localities. Most of them are primitive and many of them have been in use for centuries without appreciable improvement. Among them the bamboo stake traps (Poh) are the most important being responsible for about 70% of the total catch of marine fish.

In many instances the gear used in Thailand, such as cast-net, gill-net, purse-seine, long-line etc. are not definitely of local origin; at least, there are exact counterparts in many other countries.

The following notes include information obtained by the writer personally as well as material accumulated by other fisheries officers of the Thai Fisheries Department in the course of several years.

The descriptions given below are by no means complete, and and many remain to be added.

* The writer wishes to express his gratitude and thanks to Mr. Boon Indrambarya, Director-General, Fisheries Department, Thailand, and Dr. S. W. Ling, Assistant Regional Fisheries Officer of the F.A.O. Regional Office for Asia & the Far East for their invaluable advice and assistance in conducting the study and in preparing the report.

** Fisheries Department, Bangkok, Thailand

In this report 54 kinds of marine fishing gear employed, some of the boats and accessory equipment used to operate the gear, the fishing operations, types of catch and distribution of gear are described and illustrated.

The fishing gear described in this paper are classified as follows:—

(A) *Nets*

(1) *Moving*

(a) Trawl—none in use commercially; experimental work planned.

(b) Haul—many locality types.

1. Chinese Danish seine (Uan Ko chan)
2. Stolephorus seine (Uan tua bang)
3. Big Stolephorus seine (Uan pla hua on)
4. Beach seine (Uan koei)
5. Bagless seine (Uan play or Uan pla yai)
6. Simple seine (Pukard Mirung)
7. Hand seine (Chan nah)

(c) Cast—several locality types.

8. Cast net (Hae)
9. Shrimp Cash Net (Hae kung)

(d) Thrust and Scoop—several locality types.

10. Shrimp Scoop Net (Rawa run kung)
11. Prawn Scoop Net (Rawa run koei)

(e) Dredge

12. Sea Cucumber Dredge (Crad pling or Sai pling)

(f) Encircling

13. Chinese Purse Seine (Uan tang keh)
14. Thai Purse Seine (Uan lard or Uan dum)

(g) Encircling Gill Net—many locality types

15. Rastrelliger Gill Net (Uan pla lang or Kud pla lang)
16. Mullet Gill Net (Uan pla krabawk)
17. Sea Bass Net (Uan Pla kaphong)
18. Threadfin Net (Pukard rangin)
19. Butterfish Net (Pukard ba wai)
20. Drift Gill Net (Kad ta lang yai)

(h) Bag

21. Butterfish Bag Net (Uan ba wai or Uan charamed dum)

(2) *Stationery*

(a) Set Gill—none in use

(b) Set Barrier

22. Barrier Net (Uan pid bang)

(c) Set Bag

23. Stone-fence set net (Lard hin)
24. Reversible set bag (Teesukung or Pongpang luk loi)
25. Set Bag (Pongpang luk)
26. Wing Set Bag (Pongpang peek)

(d) Lift—many locality types

27. Lift net (Yaw)
28. Four Boat Lift Net (Uan yaw chub pla-kratak)

(e) Crab Net

29. Crab Net (chan or yong)
30. Circular Crab Net (Rio)

(B) *Lines*

(1) *Baited*

(a) Hand line

31. One-hook (Bed deo)
32. Two-hook (Bed ku)

(b) Pole and line

33. Pole and line (Bed rao pla kapong)

(c) Long line

34. Baited long line (Bed rao pla kulao)
35. Baited Shark long line (Bed rao pla chalarm)
36. Silk tassal set line (Rao pla tong)

(d) Troll

37. Sail-boat troll (Bed lark)
38. Sampan troll (Bed lark)

(2) *Nonbaited*

(a) Troll—similar to the baited troll.

(b) Jigs—none in use.

(c) Long line.

39. Ray long line (Bed rao rawai)

(C) *Traps*

(1) Simple—many locality types.

(a) Galvanized wire

40. Hood-shaped trap (Lawb prathun or lawbluad)

(b) Bamboo and rattan

41. Rectangular Bamboo Trap (Sai tang or Booboo puloh)
42. Cylindrical Bamboo Trap (Sainawn or luab)
43. Cone-shaped Bamboo Trap (Cheng leng)

(c) Bush

44. Bush trap (Krum)

(2) Multiple—many types

45. Poh—stake trap (Poh)
46. Small bamboo stake trap (Lamu or kleng or lad)
47. Netting trap (Uan pid aow or Uan rung)
48. Bamboo fence trap (Fueak karang karn or Fueak rung)
49. Bamboo net trap (Chantha)

(D) *Catch-boat*—several types

50. Catch-boat (Rua kread)
51. White board catch-boat (Rua phee lawk)
52. Simple Catch-boat (Yaw ngat)

(E) *Miscellaneous*

53. Harpoon (Chamuak deo)
54. Crab hook (Kaw luangpoo)

1. UAN KO CHAN (Chinese-Danish Seine)

Construction

The wing consists of four sections of which sections A, B and C are made of cotton netting with 6 cm., 7 cm. and 5.7 cm. meshes respectively. section D is of ramie netting, with 2 cm. mesh.

The bag is made of ramie netting, with 2 cm. mesh. The circumference is 25 meters at the entrance and 3 meters near the cod end.

Head line and ground line are of manila ropes, 0.4 cm. and 0.3 cm. in diameter respectively. The ground line is shorter than the head line.

Wooden floats are 12 cm. in length and 8.5 cm. in diameter, spaced 85 cm. apart. Lead weights are spaced 20 cm. apart.

Drag lines are made of 3 strands coir rope, 120-180 meters long 1.8 cm. in diameter, connected with the ends of the wings with wooden swivels. Each line is provided with a number of unmovable and movable white shells, alternatively arranged and spaced 0.7 meters apart.

A cylindrical wooden buoy of about 35 cm. in length, 40 cm. in diameter at top and 30 cm. in diameter at base is provided at the end of one of the drag lines.

An iron anchor of about 15 kg. in weight with an anchar line of 70—80 meters long is connected with the drag line close to the buoy.

Operation

The seine is operated by a crew of 3—4 fishermen from a small sailing boat of 5—6 meters long. Fishing is done in waters 8—25 meters deep, with sandy or muddy bottom.

In encircling fish the anchor and buoy are laid down first, then followed by the rest of the net. During hauling, by shaking the drag lines, the movable shells are made to hit the unmovable shells repeatedly, producing sound which helps to drive fish into the bag.

Catch

Mostly bottom fish or fish living just off the bottom, shrimps and crabs.

Distribution of Gear

Used mostly on the coast of Puket Province. Employed all year round but September is the best season.

2. UAN TUA BANG (Stolephorus Seine Net)

Construction

This gear is constructed on a small trawl principle, consisting of a pair of wings and a bag all made of cotton netting.

Each wing is made up of 4 sections: section A (the outermost section) is 16 meters long and 6 meters high, with 6.3 cm. mesh; section B is 5.3 x 6.3 meters in size, with 5 cm. mesh; section C is 26.2 x 6.3 meters in size, with 3.5 cm. mesh; section D is 13.2 x 6.75 meters in size, with 3.5 cm. mesh. Total length of each wing is 60.7 meters.

The bag is about 7.4 meters in length, made up of 3 sections of different mesh sizes, 1.8 cm. mesh near the entrance, followed by 1.55 cm. mesh and ends up with 1.5 cm. mesh at the cod end.

The head and ground lines are made of coir ropes. The two hauling lines are both 120 meters long; one made of coir and the other made of rattan.

Wooden floats, 12 x 5 x 6 cm., are fixed to the head line, spaced 43 cm. apart.

About 65 lead weights are fixed to each wing, spaced 85 cm. apart.

Operation

The trawl, operated from one medium size sailing boat with a 5 crew, is used in coastal waters of 8-10 meters in depth on sandy and muddy bottoms.

As soon as a school of fish is detected, a long wooden pole is firmly set on the sea bottom, serving as anchorage. The end of the rattan hauling line is tied to the wooden pole and the net is laid from the boat to surround the fish. After completing the circle the boat is tied to the wooden pole and the net hauled up.

Catch

Chiefly Stolephorus, sometimes Caranx & Cybium are also caught. During a good fishing season, the catch during one haul may be as high as 1,000 kg.

Distribution of Gear

Used mostly in Puket Province. Fishing is done whole year round, but January to February is the best fishing season.

3. UAN PLA HUA ON (Big Stolephorus Seine)

Construction

Each wing consists of two sections: the end section is made of cotton netting 40 meters long and 7 meters high, with 0.5 cm. mesh; the inner section is made of ramie twine netting, 80 meters long and 7 meters high, with 0.2—0.3 cm. mesh.

The bag is made with the same material as that for the inner section of the wing. It is 7 meters in length, with a circumference of about 23 meters at the entrance and 4.5 meters near the cod end.

Head and ground lines are made of either coir or cotton, about 1—1.5 cm. in diameter.

Wooden floats of three different sizes and shapes are used, spaced 25 cm. apart. Lead weights are spaced 8 cm. apart.

Drag lines are made of coir, 2 cm. diameter, each is 100—150 meters long.

Operation: This gear is operated by a team of 13—15 fishermen, from a boat of 12—14 meters long, in shallow waters of 2—8 meters deep with sandy or muddy bottoms.

When a school is detected the end of one of the drag lines carrying a big buoy is laid down and one fisherman gets into the water to hold the line. When the fish are encircled two more fishermen get into the water to close up the bottom of the net by bringing the ground lines together.

Distribution of Gear: Mostly in Rayong Province of the East Coast of the Gulf. August to April is the usual fishing season.

4. UAN KOEI (Beach Seine)

Construction: The wings are 21 meters in length, 1.9 meters in depth at the free end and increase gradually up to 4.5 meters at the pocket end. Made of fine hemp twine, with 2 cm. mesh.

The pocket or cod-end is 18 meters long and about 1 meter in circumference near the end. Made of hemp twine, mesh 1.5 cm. at the edge and diminishes down to 1 cm. at the end.

Head lines and foot lines are all made of 4 strands coir, 1.5 cm. in diameter. Hauling lines two in number, both 90 meters long, one made of 4 strands coir, 2.5 cm. in diameter, the other made of rattan rope, 1.8 cm. in diameter.

Floats are 7 cm. in length and 5 cm. in diameter, made of wood and are spaced 15 cm. apart.

Weights, 2 cm. in length, 0.3 cm. in thickness, made of lead sheet, spaced 1 meter apart.

The complete net costs approximately 7,000 Baht.

Boat: Sampan 6—9 meters long is used.

Fishing Operation: Each seine is operated by a group of 18 fishermen (sometimes more). As soon as the net is set the leader of the group takes up a position in the boat behind the wing along side the cod-end, directing the hauling. About 2/3 of the crew work on the haul lines from the beach while the remaining 1/3 swim in water, driving fish into the net. On the Indian Ocean side December to April is the best fishery reason.

Catch: Prawns, anchovies and other shore fishes. The catch is divided into 2 halves, one half goes to the owner of boat and seine and the other half is equally divided by the fishermen.

Distribution of Gear: Along the coast of Pangga Province on the Indian Ocean side as well as the East and West coasts of the Gulf of Thailand.

5. UAN PLAY or UAN PLA YAI (Bagless Seine)

Construction: The net is not provided with a pocket. It measures 85 meters long, 5.5 meters high at the center and 3 meters high at both ends. The mesh of the net graduated from 7.5 to 2.5 cm.

The head and ground lines are of coir, 2 cm. in diameter. The hauling lines are 90 meters long two for each wing: the upper one is of rattan, 2.5 cm. in diameter; the lower one is of coir, 3 cm. in diameter.

Floats are made of wood, 8.5 cm. in length and 5 cm. in diameter. They are spaced 75 cm. apart.

Operation: Operated from beach by a group of 18 fishermen. Sampan 9—10 meters long is used for laying the net.

Catch: Cybium, Caranx, Rastrelliger. The catch is usually divided into two halves, the owner of the gear and boat gets one half and the other half is equally divided among the fishermen.

Distribution of Gear: Along the West coast (Indian Ocean side) of Thailand. The best fishing season is from December to April.

6. PUKARD MIRUNG (Simple Beach Seine)

Construction: The seine is a single piece net without pocket, made of 12 threads cotton twine, 75—80 meters long, 1.75 meters deep at both ends and 2.5 meters deep at the center, with 2.5 cm. mesh throughout.

Head line and foot line made of 3 strands coir rope about 0.5 cm. in diameter.

Floats are made of wood, 8-10 cm. in length and 5 cm. in diameter for the middle part and smaller ones about 3 cm. in diameter for the two ends of the net. 450—500 floats are used for one net.

Weights are 3 cm. in length and 0.3 cm. in thickness, made of lead sheet, fastened to the foot-line at a distance of about 50 cm. apart. About 15 meters of both ends of the net are not provided with weights.

Each end of the net is fastened to a strong wooden beam about 1.8 meter long.

Boat: Ordinary small sailing boat about 6—7 meters long.

Three fishermen operate the net as a group. Fishing is done in shallow water about 2—3 meters deep. The gear is used mostly during low tide period. One fisherman takes care of the boat while the other two operate the net. As soon as fish are discovered one fisherman gets down into the water holding firmly one end of the net while a second fisherman proceeds to lay the net from the boat to encircle the fish. When the end of the net is reached the second fisherman also gets into the water, the net is then dragged and hauled gradually toward the shore. Fishing Operation

Catfish, shrimps and crabs and other small shore fish. The catch is divided into 9 shares; the owner of boat and net gets 3 shares each fisherman gets 2 shares. Catch

Mostly in the Province of Stul, which is situated on the Indian Ocean side, close to Malayan territory. Distribution of Gear

7. CHAN NAH (Hand Beach Seine)

Quite similar to that of a beach seine but smaller in size. Each wing is about 15.4 meters long, consisting of 2 sections both made of 2 strands hemp twine netting. The first section is 1.4 meters in length, with 4.7 cm. mesh. The second section is 14 meters long, mesh 2 cm. Construction

The bag is about 35 meters long with a circumference of about 1.3 meters near the end, made with the same netting as for the second section of the wing.

Head lines and one of the two foot lines are made of hemp ropes, 4 cm. in diameter. The other foot line is made of coir rope of 2 cm. in diameter.

Floats are made of wood, 10 x 6 x 4.5 cm., tied to the head line approximately 55 cm. apart.

Weights are made of lead sheet, 2 cm. in length and 0.3 cm. thick. 10 weights are used for each wing.

Each end of the net is fastened to a strong wooden beam of 80 cm. in length. Each beam is provided with an upper and a lower beam line which are joined together to form a loop to which to tie the haul-line.

Type and size of boat used and method and locality of fishing are similar to that of the *Pukad mirang*. This gear is used all year round but the best season is June to July (rainy season) when the salinity of the shallow area waters is low. Fishing Operation

Shrimps, crabs, mullet and other small fish. The catch is divided into three shares; the owner of boat and gear gets one share and each of the two fishermen one share. Catch

Mostly in Puket Province, on the Indian Ocean side. Distribution of Gear

8. HAE (Cast Net)

Made of cotton or ramie twine, conforming to the usual cast-net design, with build-in pockets at the margin. Various sizes are used. A typical one is about 5.2 meters high (from tip of cone to the margin) with 4.5 cm. mesh, provided with a chain of light lead rings at the edge as sinker. Cast line made of cotton, about 3.6 meters long. Construction

Operated by one man mostly from a small sampan but sometimes from shore or standing in water. The net is cast in such a manner as to fall over a group of fish and entrap them in the marginal pockets. Operation

All kinds of on shore fish. Catch

Very popular throughout Thailand, used on all types of waters, throughout the whole year. Distribution of Gear

9. HAE KUNG (Shrimp Cast Net)

The constructional details and methods of operation of this gear are very similar to those of a typical Hae (Cast Net), but is small in size, measuring only 1.52 meters from tip of cone to the margin of net and there is no marginal pocket. The net is made entirely of cotton netting, with 2 cm. mesh. The number of mesh is 33 at the tip of the cone and increases gradually to 481 mesh at the margin.

Used all year round in shallow waters 0.9—1.5 meters deep with sandy or muddy bottom, along the sea shore, in mangrove swamps and estuarine areas. Catch consists mostly of shrimps. Gear popular throughout Thailand.

10. RAWA RUN KOONG (Shrimp Scoop Net)

Figure 1

Fine cotton netting of 2 cm. mesh, triangular in shape, about 4 meters long and 6 meters at the broad end, supported by two long bamboo poles which are fastened together to form a fulcrum point as figured. A wooden shoe is fitted at the end of each pole to facilitate easy Construction

gliding on the sea bottom. The net is fastened to the bamboo frame with cotton rope and carries small lead weights at its front edge.

Boat: Small ordinary sampan is used.

Fishing Operation: One fisherman operates one gear, working in shallow waters 0.2—1.5 meters deep, along the coast and brackish water areas. Fishing is done all year round day and night, whenever the sea is calm and weather fair. The fisherman holds the fulcrum point of the bamboo frame, sets the front edge of the net down to the sea bottom and pushes the net forward while dragging the boat behind him. When sufficient shrimps are accumulated, the net is lifted and the catch emptied into containers kept in the boat, and the operation repeated.

Catch: Mostly shrimps. Small fish are also caught.

Preservation of Net: An emulsion prepared from a mixture of egg white from 20 eggs and ¼ liter of Tung-oil is used as preservative. After being thoroughly soaked in the freshly prepared preservative the net is sun-dried, then steamed for 1—2 hours and finally sun-dried again. One treatment per month is required.

Distribution of Gear: Along the entire coast of Thailand.

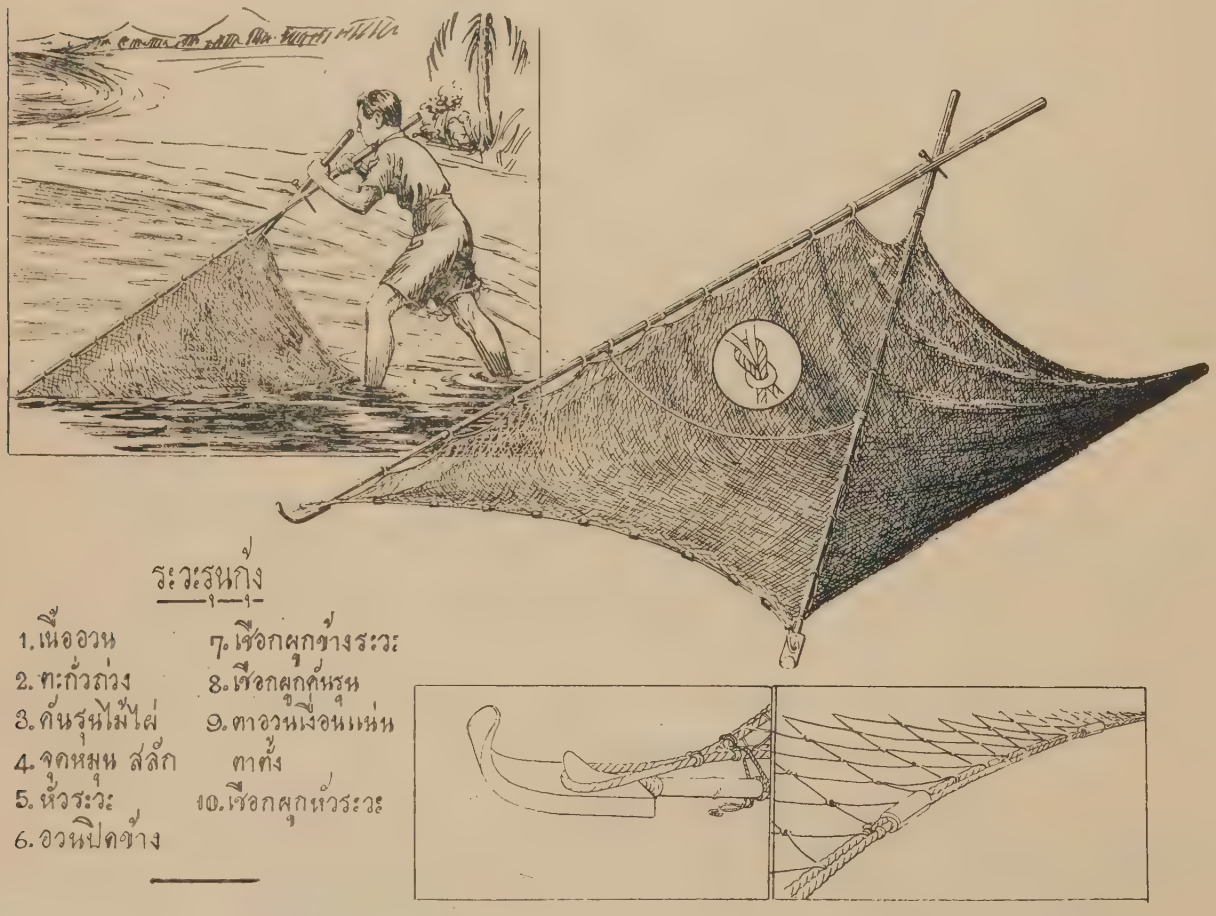


Fig. 1. Shrimp Scoop Net

11. RAWA RUN KOEI (Prawn Scoop Net)

Quite similar to that of the shrimp scoop net, except that it is made of fine meshed hemp netting and the base of the net is provided with a cylindrical catch-bag.

Tannic acid solution obtained from soaking mangrove bark in fresh water is used for preserving the net.

12. CRAD PLING or SAI PLING (Sea Cucumber Dredge)

Figure 2

Construction

Frame of dredge made of heavy wood, about 6 meters in length, 40 cm. in height and 20 cm. in depth. Each of the two lateral bottom bars of the frame is provided with a split rattan cane, known to the fishermen as the "tail". The tails project beyond the hind margin of the dredge for about 30 cm., providing a smooth surface for easy dredging and at the same time keeping the dredge closely applied to the sea bottom.

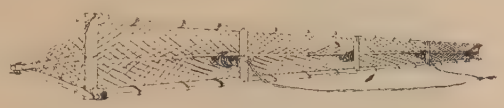


Fig. 2. Sea Cucumber Dredge

Stones of about 300—400 grams in weight are used as sinkers which are fastened one to each of the 3 bottom cross bars of the frame. The weight of the sinkers used depends upon the depth of water and speed of current under which the dredging is done.

The top, bottom and sides of the dredge are covered with netting made of 0.15 cm. hemp twine, with 6.5 cm. mesh.

The dredge line is about 250—300 meters in length, 3 cm. in diameter length and made of either coir or fibre of tree bark.

Boat

Small Malayan type sail-boats about 6—7 meters long 1.2—1.5 meters wide are used. Each boat carries a 6-men crew.

Fishing

Fishing is done mostly along the West coast of Thailand (Indian Ocean side) in a depth of 10—30 meters. Fishing season starts in November and ends in May, but February and March are the best months. Upon reaching the fishing ground the dredge is lowered down to the bottom of the sea, the crew then row the boat forward until the entire dredge line is released, the boat is then anchored and the dredge hauled to the boat dragging it slowly along the sea bottom. Each dredging operation requires about 1 hour to complete.

Catch

Sea cucumbers. The catch is washed, cleaned, boiled in sea water and sun-dried.

When the boat and gear is not operator owned the total catch is divided into 8 shares; 2 portions for the boat and gear and one for each of the crew.

Distribution of Gear

Confined to the West coast (Indian Ocean coast) of Thailand, mostly in Puket Province.

13. UAN TANG KEH (Chinese Purse Seine)

Figure 3.

Construction

Net made of 5 sections of cotton netting, total length about 220—250 meters, 50 meters high at the middle and 6—10 meters high at the ends, with 1.5—3 cm. mesh.

Head and foot ropes are made of cotton, 0.75 cm. in diameter.

Wooden floats are spaced 10—15 cm. at the end sections and 8—10 cm. for the rest.

Lead weights are cylindrical shaped, each weighing about 1/4 kg., a total of 250—300 weights are used in one net.

Purses rings are made of brass, 8.3 cm. in diameter. Each net uses about 100 rings.

Purse lines are made of cotton, 2.2 cm. in diameter, each is 130 meters in length. Two lines are used, connected together with a swivel at the central part of the net.

Boat

One powered boat 15—19 meters long, 2.8—3.2 meters wide and 1.5—2 meters deep, with 30—60 H.P. engine, and two small sampans are needed for operating this gear. Insulated holes are provided in the powered boat for storage of catch.

Operation

17 fishermen are required in the fishing operation. Fishing is done in waters 10—30 meters deep with sandy or muddy bottoms; from February to December. The two sampans each carrying half of the net are towed by the powered boat to the fishing ground. Each sampan carries 7 fishermen who are responsible for laying the net to surround the fish and to drag the purse lines. The final step of hauling and removing catch is done by the fishermen on the powered boat.

Catch

Mostly Rastrelliger. The total income from each fishing voyage after deducting expenditures on food, ice and fuel, is divided as follows:—the boat-owner gets 32%, net-owner 32%, leading fisherman 2.5% and the rest is divided into 20 to 22 parts of which the head fisherman gets 2 parts, assistant fishermen 1½ parts and each fisherman 1 part.

There are about 80 sets of net now in operation, distributed in Samuth Prakran, Samuth Sakorn, Samuth Songkram, Prachub, Cholburi and Petchburi.

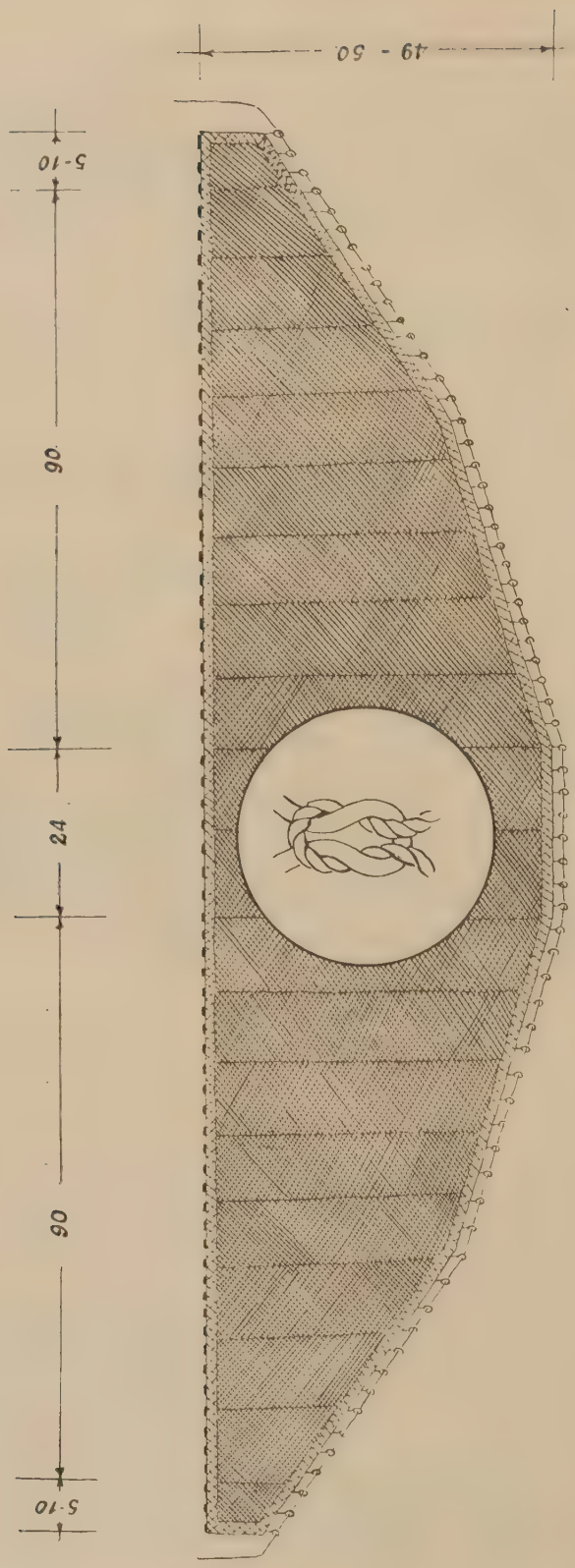


Fig. 3. Chinese Purse Seine

14. UAN LARD or UAN DUM (Thai Purse Seine)

Made principally from cotton netting with 1—2 cm. mesh. Each set of net consists of two separate unconnected halves. Total length 500 meters, depth 17 meters. Nets of smaller dimension are also used. — Construction

Head and foot lines are made of cotton ropes, 0.75 cm. in diameter.

Purse rings are made of brass, 8—10 cm. in diameter, spaced 1 meter apart.

Purse line are made of cotton ropes, 530—560 meters in length and 2.2 cm. in diameter.

2—4 small sailing boats of 8—8.5 meters long with a crew of 20—24 fishermen are needed to operate one set of net. Fishing is done in waters 6—14 meters deep with sandy or muddy bottom. — Boat

A wooden pole, 10—15 meters long and 10—20 cm. in diameter is used for hauling the purse line. One end of the pole is tied to the boat while the other carries a pulley. As soon as the fish are encircled the pole is put into water and with the help of a diver the purse line is inserted through the pulley, to facilitate easy closing of the purse net. — Operation

Mostly Rastrelliger. Various kinds of Clupeoids are also caught. — Catch

After taking out expenses for food the remaining income from each fishing trip is divided into 30 portions; gear owner gets 9 portions, each of two chief fishermen 1½ portions, each experienced fisherman 1 portion and each apprentice fisherman ½ portion.

Along the coast of Samuth Prakran, Samuth Sakorn, Samuth Songkram, Prachub and Chumporn. Bigger nets are used 9 months of the year, March to December, while smaller nets are in operation all year round. — Distribution of Gear

15. UAN PLA LANG or KUD PLA LANG (Rastrelliger Gill Net)

Net made of hemp twine netting, with 5.7 cm. mesh. Each unit is 24 meters in length and 7.5 meters high. 4 units connected end to end to make a complete set. — Construction

Head and ground lines are made of manila ropes of about 1.5 cm. in diameter.

Floats are made of wood, 25 x 7 x 3 cm. fixed to the head line 45 cm. apart.

Weights are made of lead rods about 1.5 cm. in diameter and are attached to the ground line 90 cm. apart.

Small sailing boats about 6—7 meters in length are used, carrying a crew of 4 fishermen. — Boat

This net may be used in waters of 8—50 meters deep. Fishing operations can be carried out both day and night. When a school of fish is discovered the net is laid to surround them and by beating the water with sticks the fish are frightened and while trying to escape will be gilled to the meshes. — Operation

Mostly Rastrelliger. The catch is usually divided into 7 shares; the boat and gear owner takes 3 shares while the rest is equally divided among the fishermen. — Catch

Along the West Coast (Indian Ocean side) of Thailand. — Distribution of Gear

16. UAN PLA KABAWK (Mullet Gill Net)

Net made of ramie twine, with 6 cm. mesh. Each unit is 30 meters long and 4 meters high. 5 units joined end to end to make one complete net. — Construction

Head and ground lines are of manila rope, 0.4 cm. in diameter.

Wooden floats are 25 x 10 x 3 cm., spaced 65 cm. apart.

4-man crew operates the gear, from a boat of 8—10 meters long, in shallow shore waters of 2—4 meters deep with sandy or muddy bottom. Fishing is done both day and night. After the fish is encircled by the net the fishermen beat the water with their oars to drive the fish towards the net. — Operation

Mullets and Thread-fins. — Catch

In the Southern Provinces along the Indian Ocean coast and the coasts of the Gulf. The best fishing season for the Indian Ocean side coast is from November to April. — Distribution of Gear

17. UAN PLA KAPHONG (Sea Bass Net)

Net made of ramie twine, with 12—15 cm. mesh. Each unit is 22 meters long and 2.1 meters high. 9 units are needed to make up one complete net. — Construction

Head and ground lines are made of manila rope, about 0.3 cm. in diameter.

Wooden floats are 25 x 10 x 3 cm., spaced 65 cm. apart.

Operated by a 4-man crew from a sampan about 8—10 meters long, in shallow shore or brackish water areas, in a depth of 1—2.5 meters, on sandy or muddy bottom. The method of catching is similar to that of mullet gill net. — Operation

Mostly sea-bass. — Catch

Along the coast of Ranong Province on the Indian Ocean side and also along the East and West coast of the Gulf. — Distribution

18. PUKARD RANGIN (Thread-fin Net)

Construction: Quite similar to that of the mullet gill net but with the following differences:
(1) each unit is about 21.5 meters long and 1.75 meters deep, with 7 cm. mesh;
(2) both head line and foot lines are used, made of 4 strands manila rope of 0.5 cm. in diameter;
(3) wooden floats 10 cm. in length and 5 cm. in diameter are used at both ends of the net, while 8 cm. long floats are used in between the two ends, the floats are spaced 17 cm. apart.

Fishing Operation: A small sailing boat about 6.5 meters long with a five-man crew operates as a unit. Fishing is done in very shallow waters, about 0.5—1.5 meters deep, from December to April, while February is the best fishing month. This gear is used only in daytime. Four units of net are employed to form one set. When a school of fish is detected one of the crew gets into the water holding one end of the net while the rest of the net is laid from the boat to encircle the fish. The net is then drawn closer and closer thus narrowing the circle and concentrating the catch.

Catch: Mostly thread-fins. The catch is divided into 6.5 portions; 1 for boat, 0.5 for net, and 1 for each of the 5 fishermen.

Distribution of Gear: Along the coasts of Trang Province and Gulf of Thailand.

19. PUKARD BA WAI (Butter-fish Net)

Construction: Quite similar to that of the mullet gill net except that each unit is 28—30 meters long and 4.7 meters deep, made of 2 strands hemp twine of 0.2 cm. in diameter, with 14 cm. mesh.
The wooden floats are 16 x 3 x 2 cm., spaced 47 cm. apart.

Fishing Operation: Small sailing boat about 5—6 meters long is employed. A two-man crew takes care of the entire operation. Fishing is done almost exclusively on dark nights, about 12 days in a month, during October to May. The nets are set across the current in waters of about 5—8 meters deep. Five units of net are joined end to end to form one set which has a total length of 140—150 meters. One end of the net is free while the other is tied to the boat with one or two buoys fixed between them.
The net is left drifting for the whole night and is hauled up at dawn.

Catch: Mostly flat-fish and rays. The catch is divided into 3 equal portions; one for the boat and gear and one for each of the two fishermen.

Distribution of Gear: Along the coast of Trang Province on the Indian Ocean side of Thailand.

20. KAD TA LUNG YAI (Drift Gill Net)

Construction: Made of units 24 meters long and 8—9 meters deep. The netting is made of 2-strand hemp twine of 0.2 cm. diameter. The mesh is 18 centimeters.
The head line is made of 4-strands manila rope, 0.5 cm. diameter. No ground line is necessary.
Floats are made of wood, each is about 21 x 4 x 2.2 cm. They are tied on the head line, spaced about 65 cm. apart.
Buoys are made mostly of bamboo, each measures about 45 cm. in length and 11 cm. in diameter. 16 buoys are used for one complete set of net.

Boat: Ordinary small sailing boats, about 6—8 meters in length and 1.7 meters in breadth are used.

Fishing Operation: 4—6 fishermen work as one team. In fishing operation 6 units of nets are fastened together end to end to form one set. Fishing is done at night all year round but mostly in calm seasons, in shallow waters, 10—30 meters deep, along the coast or around islands.
The net may be used as a ring gill net when fish occur in school. As sooon as a school of fish is detected judging from the characteristic glow of sea water caused by the movement of the fish, the net is set to encircle them. When the fish are surrounded, light or sound are used to frighten them and drive them into the net.
When used as a drift net it is set across the current with one end tied to the boat.

Catch: Mostly Scomberoid, and Cybium.

Distribution of Gear: Along the coast of Krabi Province, Indian Ocean side of Thailand.

21. UAN BA WAI or UAN CHARAMED DUM (Butterfish Bag Net)

Figure 4, 4a

Construction: The essential items of this gear are a cone-shaped bag net, a series of fish lures and a small sailing boat.
The net is cone-scoop shaped, made up of 3 parts of cotton netting as shown in figure . Part A is 30 meters long and 20 meters wide, mesh 9 cm. Part B is 10.5 meters long and 20 meters wide, with 6.5 cm. mesh. Part C (the bag) is 20 meters long, and about 1 meter

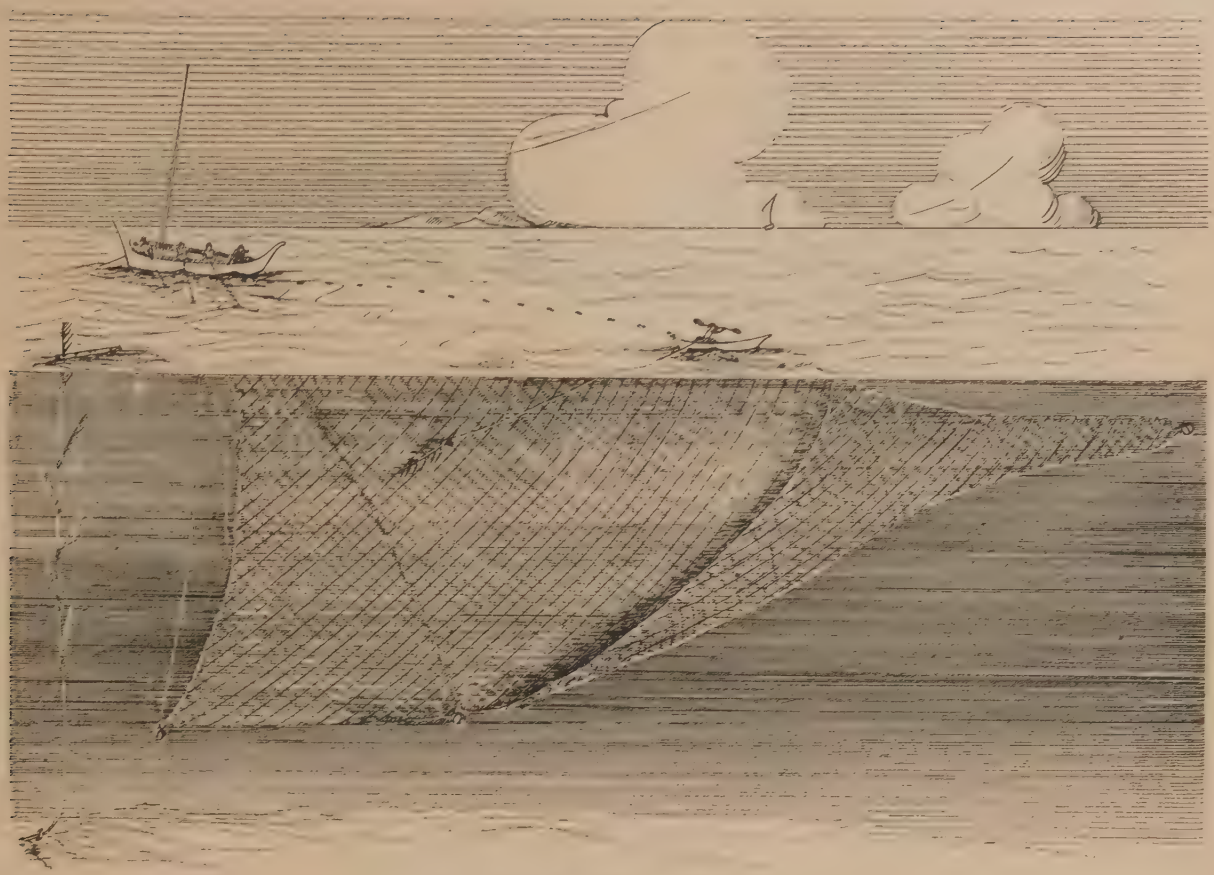


Fig. 4. Butterfish Bag Net

Fig. 4a. A Fish-lure

in diameter near the cod end, mesh 6 cm. Both head and ground lines are made of cotton ropes. Coir ropes are used as lift lines and buoy lines. The guide line is made of manila rope.

22 wooden floats are fixed on the head rope, each measuring 15 cm. long, 5 cm. in diameter at the middle.

Two stone weights are used; one is about 5 kgs. attached to the lower fore angle of the net, the other is attached to the middle part of the net and weights about 2 kg.

The fish lures consist of a series of vertically set lines. Each line consists of a piece of coir rope about 45 meters in length and 2.2 cm. diameter, a wooden anchor at the lower end, a bamboo float on the upper end and with cocoanut leaves or palm leaves tied into 4 or 5 small bushes between the two ends of the line.

Fishing Operation: One fishing team consists of 6 fishermen. Fishing is done only in day time, in waters 16—45 meters deep. Upon reaching the fishing ground by a small sailing boat, the lure lines are set in a long row across the current, spaced about 50—100 meters apart. When sufficient numbers of butterfish, attracted by the bushy cocoanut leaves, are gathered around the lures, the net will be set and at the same time a fish guide line (a manila rope, 25 meters long and 0.8 cm. in diameter, with a bundle of cocoanut leave and a small lead weight tied at the end) will be laid from a small boat to guide the fish into the net.

Catch: Only butterfish, *Stromateus cinereus* are caught. The catch is divided into 7 shares; 1 share for boat and gear, and the rest divided equally among the crew.

Distribution of Gear On the East and West coast of the Gulf and on Krabi Province on the Indian Ocean coast. Fishing season starts from March and ends through November, but September is the best time for using this gear.

22. UAN PID BANG (Barrier Net)

Construction: The trap consists of a cotton or hemp netting set on wooden poles across small brooks in estuarine areas. The netting is about 15 meters long and 2 meters in height, with 8 cm. mesh. The ground rope of the net is provided with 50—60 small wooden pikes about 50 cm. in length and 1.5 cm. in diameter each for fixing the ground edge of the net firmly to the bottom.

Fishing Operation: During low tide 15—20 wooden poles are set across the brook. The ground line of the net is then fixed firmly to the bottom by pushing the attached wooden pikes into the mud. The head line of the net remains free at this stage. When the maximum water level is reached the head line of the net is then raised and fastened as high up the wooden poles as possible without freeing the bottom line, thus forming a semicircular barrier across the brooks. The fish and shrimps accumulated in the trap during the recession of tide are removed with scoop net at low tide. Small sampan or mud sledge are used for visiting the trap.

Catch: Cat-fish, sea bass, mullets and shrimps. The catch is divided into 3 portions; 1 for the owner of the gear and the rest for the fishermen.

Distribution of Gear: Mostly used in Ranong Province on the Indian Ocean coast.

23. LARD HIN (Stone barrier trap)

Construction: This gear consists of two wings and a catch-bag. The "V" shaped wings are constructed by piling small stones about 0.5 meter high on the shore during low tide. The wings lead into a cotton netting catch bag set on a wooden frame.

Operation: During high water fishermen work with small scoop nets along the inner edge of the stone wings, starting from the shore towards the catch-bag. By so doing he catches some of the fish or shrimp present along the wings and at the same time drives the rest gradually into the catch-bag which is emptied during low water.

Catch: Small littoral fish, shrimps and crabs.

Distribution of Gear: Very popular in Krabi Province, on the Indian Ocean coast. This gear can be operated all year round but low water season gives the best catch.

24. TEESUKUNG or PONGPANG LUKLOI (Reversible Set Bag)

Figure 5

Construction: The bag is made of 5 sections of hemp twine netting as shown in the figure. The total length of the bag is about 7.7 meters long and when set in position the open end is almost square, measuring about 3 meters on each side; the body of the bag is cone-shaped and is about 27 cm. in diameter at the cod-end. The net is supported by 3 metal rings one at the junction of two major sections as shown.

Fishing Operation: Fishing is done the whole year round when the sea is calm. The net is set in shallow waters, in the direction of the current, when the tide is low. No floats or sinkers are used. The net is fixed firmly to two long wooden poles set about 3 meters apart.

In hauling, the haul-line fastened to the last metal ring is lifted. The catch is removed through the end of the bag. On average, 30 minutes is required for one hauling. When the

Fig. 5. Reversible Set Bag

catch at one place is poor, the net and poles are removed and re-set at another place. The whole process of setting the net takes about 20 minutes. This net is reversible to fish and once set in a favourable position may be used for both ebb and flow.

Catch — Shrimps and small fishes.

Preservation of Net — Net treated once a month with egg-white Tung-oil emulsion, sun-dried, steamed and sun-dried.

Distribution of Gear — All along the coast of Thailand, especially popular in brackish water areas.

25. PONGPANG LUK (Set Bag)

Quite similar in shape, construction, operation and distribution to that of Pongpang Lukloi, but is larger and the frame for fixing the net is stronger and is held firmly by anchors.

26. PONGPANG PEEK (Wing Set Bag)

Construction — The shape, construction, method of operation, distribution and preservation of the net are quite similar ot those of Pongpang Lukloi, but in this gear two wings are used; each consists of 300—500 wooden poles set 30—40 cm. apart in a long row diagonal to the opening of the bag.

The two bottom angles of the mouth of the bag are each provided with 2 rattan rings which are fastened to the arms of the horse-shoe shaped end piece of the depth controlling pole. In setting the net the horse-shoe shaped end piece is slipped around the frame pole and the pole lowered down until the desired depth is reached then tied on to the frame pole.

This gear is used for about fifteen days in a month when the tidal current is strong. The net is set during low tide and the cod-end is hauled for discharging catch at intervals of about 20 minutes.

27. YAW (Lift Net)

Figure 6

Construction — Net square, made of cotton netting, 2—4.5 meters to one side, margin fringed with cotton rope.

4 bamboo rods, 2—3 meters long each, are used as net spreaders which are joined together, to form a big cross at the center by inserting the big ends of the rods into the ends of a bomboo cross-frame.

A single bamboo pole is used as lever, 5—8 meters long and carrying a cotton lift line 10—12 meters long.

Operation — The net is operated by one man either from a small sampan or from shore. Catch is removed from the net with a long handled dip-net. Used in shallow waters of all types of bottom, along the coast, brackish and fresh water regions.

The net is detachable, the bamboo spreaders, cross frame and lever may be rolled with the net into a small roll for easy carrying.

Catch — All kinds of shore fish, shrimps and crabs.

Distribution of Gear — Used throughout entire Thailand, all year round.

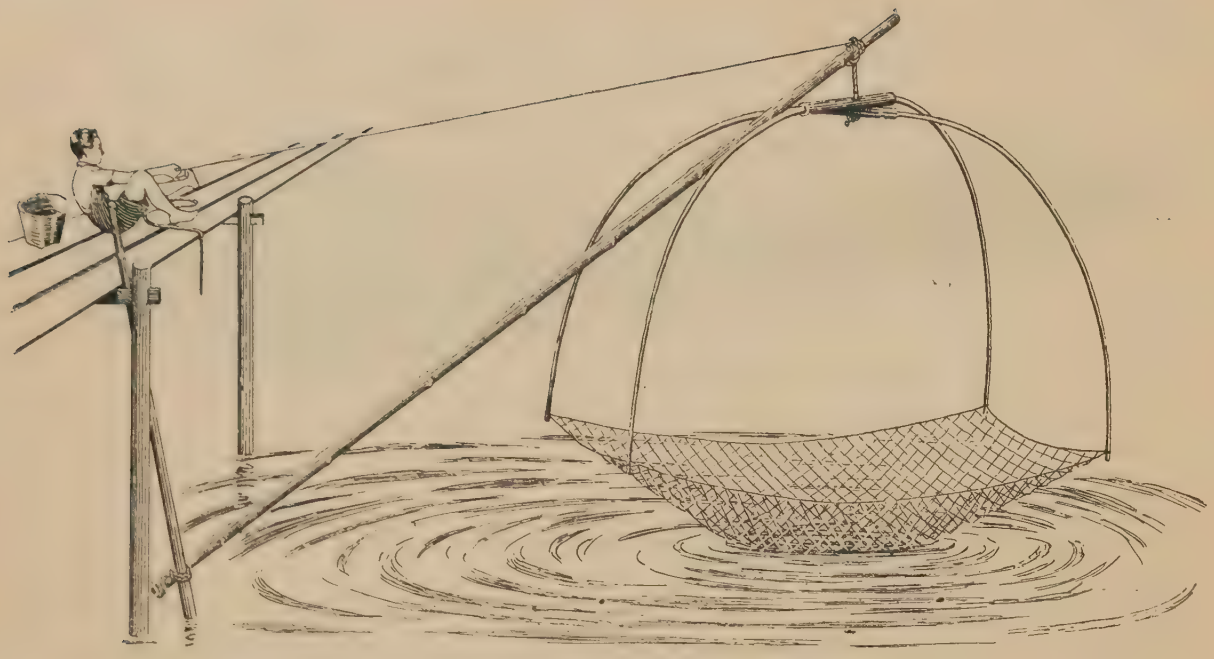


Fig. 6. Lift Net

28. UAN YAW CHUB PLA-KRATAK (Four-Boat Life Net)

Construction: Net made of both cotton and ramie twine netting. The centre piece is of ramie, 10 meters square with very fine mesh. The outer portion of the net is made up with 4 side piece of cotton netting, each measuring 15 meters long and 5 meters wide, with 1.25 cm. mesh. The side pieces and the central piece are joined together to form a large net of 20 square meters.

The margine of the net are strengthened with 2 coir ropes of 1 cm. diameter.

Each corner of the net is provided with a stone sinker 8—10 kg. in weight, and is connected with a coir lift line 6 meters long.

Boats: 5 small sampans, 7—8 meters long.

Operation: 10—15 fishermen are required for operating a set of gear. Fishing is done only in dark nights, in all types of shallow waters of 4-6 metres.

Four of the five boats of the team, will anchor each near a corner of the net and holding one of the life lines. The net is lowered by releasing the four lift lines simultaneously from the four boats. The fifth boat carries a bright light (from burning oil or wood) and moves around slowly. When sufficient fish are attracted to the light the boat then proceeds slowly, leading the fish to the centre of the net. Net hauling is then done by lifting the 4 lift lines at the same time by the four boats.

Catch: Mostly Stolephorus.

Distribution of Gear: Used in the Province of Cholburi (Goh Si Shang) on the East coast of the Gulf. June to September is the fishing season.

29. CHANG or YONG (Crab Net)

Construction: The net consists of a frame and a piece of cotton net and is controlled by floats and sinkers. The frame is made of 2 pieces of bamboo each about 60—70 cm. in length which are tied together at their middle to form a cross.

The net is made of 10 threads, 2 strands cotton twine, mesh 4—6 cm. Small stones of about 200 grams are used as sinkers, one tied near the tip of each net frame. A wooden float is connected to the centre of the frame by a cotton float line of from 1—8 meters in length.

Bait: Small fish are used as baits and are tied beneath the centre of the frame.

Boat: Small sampan or small sail-boat, with one man crew.

Fishing Operation: Fishing is done whole year round, day and night, along the coast, especially in well protected areas, lagoons and mangrove region. The nets are set by adjusting the length of the float line so that the bottom of the net is barely touching the sea bottom. One fisherman sets

15—50 nets in a long row and works continuouosly from one end to the other in removing the catch, rebaiting and re-setting.

Mainly shore crabs (*Scylla serrata*) and some blue crab (*Portunus pelagicus*). — Catch

Along the entire coast of Thailand. — Distribution of Gear

30. RAEW (Circular Crab Net)

A circular cotton netting, 40—50 cm. in diameter, with 5—8 cm. mesh, fixed on a rattan ring. The net is tied to a small wooden pole by four strings, with one end of the pole passing through the centre of the net. — Construction

Baits, usually fish flesh, are tied near the centre of the net. — Bait

Two fishermen work as a team from a small sampan; one rows the boat and the other operates the gear. — Boat

The nets are set with their bottoms barely touching the sea bottom in shallow brackish waters, mangroves and estuarine areas. 20—70 nets are set about 8—15 meters apart in a long row. 10 to 15 minutes are allowed for crabs to come to take the bait. The fishermen work from one end of the row to the other, remvoing the catch, re-bating and re-setting the net. — Operation

Catch consists mainly of crabs, *Scylla serrata*, while shrimps are also occasionally caught. — Catch

The net is popular along the East and West coasts of the Gulf and fishing is done during daytime all through the year. — Distribution of Gear

31. BED DEO (One Hook Hand-line)

Line made of 75 threads of No. 20 cotton yarn, about 20—30 meters long. Hooks used are of various sizes and shape depending upon the kind of fish to catch. — Construction

Sinkers are of lead, about 4 cm. in length, weighing approximately 150 grams.

Shrimps, worms or cut up pieces of clupeiods. — Bait

Ordinary small sampan carrying one or two-man crew. — Boat

Fishing is done all year round, in shallow sea, brackish waters, estuarine areas, rivers and lakes. — Fishing Operation

All kinds of fish. — Catch

32. BED KU (Two Hooks Hand-line)

Similar to that of the one hook type except that the line is 80 meters long and 2 hooks are used instead of one. The lead sinker is 7 cm. in length and about 600-800 grams in weight. — Contruction

Ordinary small sampan or sail-boat, with either two-man or three-man crew. — Boat

Fishing is done all year round in shallow waters, 10—30 meters in depth, along the coast. During fishing operation the boat is anchored and all the crew work on the lines. — Fishing Operation

Mainly of bottom forms. — Catch

Popular throughout entire coast of Thailand. — Distribution of Gear

33. BED-RAO PLA KAPONG (Pole and line—for sea-bass fishing)

The pole is made of bamboo, about 4.1 meters in length, 2 cm. in diameter at the tip and 5 cm. in diameter at the base. — Construction

The main portion of the line is about 3.85 meters, made of No. 4 galvanized wire. A double piece of 75-thread cotton line about 30 cm. long is used for connecting the galvanized wire to the pole. A ring-like swivel is provided at the distal part of the line about 30 cm. from the hook.

Hooks are hand made by fishermen from iron wire of about 0.3 cm. in diameter, each measures about 10 cm. in length and 4 cm. in breadth. Barbed.

The cost for a pole and line is about 5 Baht.

Shrimps of various species are used. — Bait

Small sampans 6—8 meters in length and 1.2 meters in breadth are used. — Boat

Fishing is done mostly in daytime in brackish water and estuarine areas. One of the 2-man crew rows the boat while the other does the fighting. — Fishing Operation

Sea bass, *Lates calcarifer*. — Catch

In all the brackish water and estuarine area of Thailand. — Distribution of Gear

34. BED RAO PLA KULAO (Baited long line)

The main line is cotton, 0.8 cm. in diameter and 370 meters in length. Each piece carries 200 hooks. Snoods or gangens are of manila twine 1 meter in length and spaced 1.8 meters apart. Aluminium coated iron hooks of No. 4 size, about 8 cm. in length and 2.8 cm. in breadth. Each set of line costs about 300 Baht. — Construction

Boat: Small sampans 5 meters long and 1.2 meters wide are used with two fishermen crew.

Baits: Shrimps, prawns and small clupeiods are used as baits.

Fishing Operation: In laying out the line a wooden weight with stone anchor and a bamboo buoy are set at each end of the gang. A third bamboo buoy is placed at the middle. Each buoy is about 40 cm. in length and 12 cm. in diameter. These lines are set in shallow water perpendicular to the direction of current.

After the line is set the fishing or seeking time requires only 10—20 minutes. With a 2-man crew the fishermen work continuously in setting, lifting and rebaiting.

Catch: The catch consists mainly of rays, sharks, cat-fish and thread-fins.

Distribution of Gear All along the coast.

Preservation of Line: The lines are soaked in Rhizophora bark solution twice a month. The Rhizophora bark solution is prepared by soaking finely cut Rhizophora bark in water for 2 weeks.

35. BED RAO PLA-CHALARM (Baited Shark Long-line)

Construction: Main line made of 3-strand coir rope, 1 cm. diameter. Each unit measures 230-300 meters in length. It usually takes two units tied end to end to form one set, making the total length about 460-600 meters.

Snoods are 3-strand coir rope, 0.7 cm. in diameter and 1 meter in length, spaced 2 meters apart. Two pieces of No. 14 galvanized wire, 20 cm. long are used to join the hook to the end of the branch line thus making the total length of snood 1.2 meter.

Hooks are 10 cm. long and 2 cm. broad, hand made by the fishermen from iron wire. Each set of line carries 250—300 hooks. When not in use all hooks of each units are kept in a hook sheath and line coiled in a basket.

Anchors are made of either iron or stone, weigh about 10 kg. each. Each anchor line is about ½ meter long.

Buoys and floats are of the same size and material, each is made of a piece of bamboo about 10 cm. in diameter and 50 cm. in length. 2 buoys one at each end of the line and 6 floats spaced about 80 meters apart are used.

The cost of one complete set of line is 300—600 Baht.

The lines are treated with Rhizophora bark solution once a month.

Boat: Small sampan 6—8 meters in length and 1.2 meters in breadth carrying 2—3 men crew is used.

Fishing Operation: Lines are set across the current in shallow on-shore or estuarine areas about 6—20 meters in depth, at about 2/3 the depth under surface of water. Best season for fishing is when water salinity is high.

Baits: Small clupeiods and catfish are used.

Catch: Mainly sharks.

Distribution of Gear Along the entire coast.

36. RAO PLA TONG (Silk tassel set line)

Construction: The main line is 20—40 meters long, made of cotton or ramie. Snoods are made of 10-thread cotton twine, 50 cm. in length and spaced 60 cm. apart.

Instead of using hooks, tufts of silk threads about 8 cm. long are tied to the end of the snoods. Small pieces of fish flesh are used as bait which are tied just above the silk tassel.

Fishing Operation: The line is set across current in brackish waters or river mouth. Wooden poles are set first then the line is tied on to them. The main line is set just touching the surface of water. Fishes trying to take the baits will be caught at their teeth by the silk thread.

Catch: Needle fish.

Distribution of Gear Fishing is done from January to March in the Province of Surad along the West coast of the Gulf.

37. BED LARK (Sail-boat Troll)

Contruction: Made of No. 14—15 galvanized wire, 40—100 meters in length. 3—6 lines are operated by one boat.

Foreign made iron 6—8 cm. in length and 3—4 cm. in breadth. Hook barbed. Two swivels are provided between the line and the hook.

Bait: Sardine or small clupeoids are used. Bait is fastened around hook with fine copper wire.

Cost of Line: Each set of line and hook costs about 500 Baht.

Boat: Small sail-boats 6—8 meters in length, 1 to 1.5 meters in breadth and 0.6 to 0.8 meters in depth are used.

Fishing Operation: Fishing is done mostly in day time along on-shore areas about 10—25 metres deep. Each boat has a one-man crew who operates 3—4 lines. Since the boat is wind propelled the fisher-

man can operate, without stopping the boat, more lines continuously and get larger catch than fishermen in sampan trollers.

Cybium, Barracuda and other Scomberoids. — Catch

From August to May. Fishing starts at the southern part of the East coast of the Gulf and moves up north gradually as the season changes. — Fishing Season

Used mostly along the East Coast of the Gulf of Thailand. — Distribution of Gear

38. BED LARK (Sampan Troll)

Made of 3 cotton strands right hand twisted, 30 threads of No. 20 cotton yarn to each strand. Length of line 36—40 meters. — Construction

Foreign made, iron, 9 cm. in length, 4 cm. in breadth, end of shank either knobbed or ringed; hook barbed.

Various species of small clupeiods are used. Bait usually fastened around hook with fine copper wire.

The cost of line and hook is approximately 10 Baht per set. — Cost of Line

Lines are rubbed with juice of Rhizophora bark 2—3 times every month. — Preservation of Line

Small sampans approximately 6-8 meters in length and 1 to 1.2 meters in breadth are commonly used. Each boat is provided with a pair of oars. — Boat

The boat is manned by only a single fisherman who operates 1 or 2 lines. Fishing is done only in shallow waters about 6—10 meters deep along the shore. Upon reaching a favourable spot the fisherman casts out the lines and allows them to run for about 18—20 meters, then stops it with his feet while he continues to row the boat forward. By the nature of jerk of the line under his feet the fisherman knows when fish is hooked. He stops rowing, hauls up the line, removes the fish, rebaits the hook and repeats the operation. Fishing is done mostly at night or at dawn when the sea is calm and breeze gentle. Catch is collected in the hold or put into bamboo basket without ice. — Fishing Operation

The catch consists mostly of Scomberoides, Cybium, Barracudas and Lates. — Catch

All year round. — Fishing Season

Throughout the entire coast of Thailand but especially popular along the East and West Coasts of the Gulf. — Distribution of Gear

39. BED RAO PLA KABEN or BED RAO RAWAI (Non-baited Long-line for Ray Fishing)

Main line made of 4-strand manila twine, 0.5 cm. in diameter and 56 meters in length. 12—20 units form one set with a total length of 672—1120 meters. — Construction

Snoods are made of 2-strand hemp rope, left handed twisted, 0.3 cm. in diameter and 30 cm. in length, spaced 35 cm. apart.

Hooks are hand made by fishermen, iron, 5.5 cm. in length and 2 cm. in breadth, shank knobbed and hook unbarbed. Each unit carries 144 hooks.

Floats are made of wood, 5 x 2.5 x 2.5 cm. spaced 2.45 meters apart, attached to the main line by float line 3—5 cm. long.

Buoys are made of bamboo, 10 cm. in diameter and 45 cm. in length. Buoy lines made of same material as main line, each measures 30 meters in length. 13 buoys are used for one set of line.

Small sail boat about 8—10 meters in length and 2 meters in breadth, carrying 2—3 fishermen most commonly used. — Boat

13 wooden anchors are used for fixing the line. Each anchor is attached to the main line with a short anchor line at the points where the buoy lines are fastened.

The lines are set across the current in shallow waters about 10—15 meters depth. Each "Soaking" (Fishing) time is about 2 hours. Fishing with this gear is done all year round, night time as well as day time. Fishermen work only during 1 tide a day. — Fishing Operation

Rays and sharks mostly. In cases where the fishermen do not own the boat and gear, the total catch is divided into 5 equal portions; 2 portions for the owner of boat and gear and 3 portions divided equally among the crew. — Catch

Throughout the entire coast of Thailand. — Distribution of Gear

40. LAWB PRATHUN OR LAWBLUAD (Hood Shaped Trap)

Figure 7

The shape of the trap resembles the hood of a sampan, about 2.8 x 1.4 x 3.3 meters. The frame of the trap is made of wood and rattan and is covered with 2.3 cm. mesh galvanized wire netting. The chamber of the trap is provided with 2 sets of trapping device one at the entrance and the other near the center of the trap. — Construction

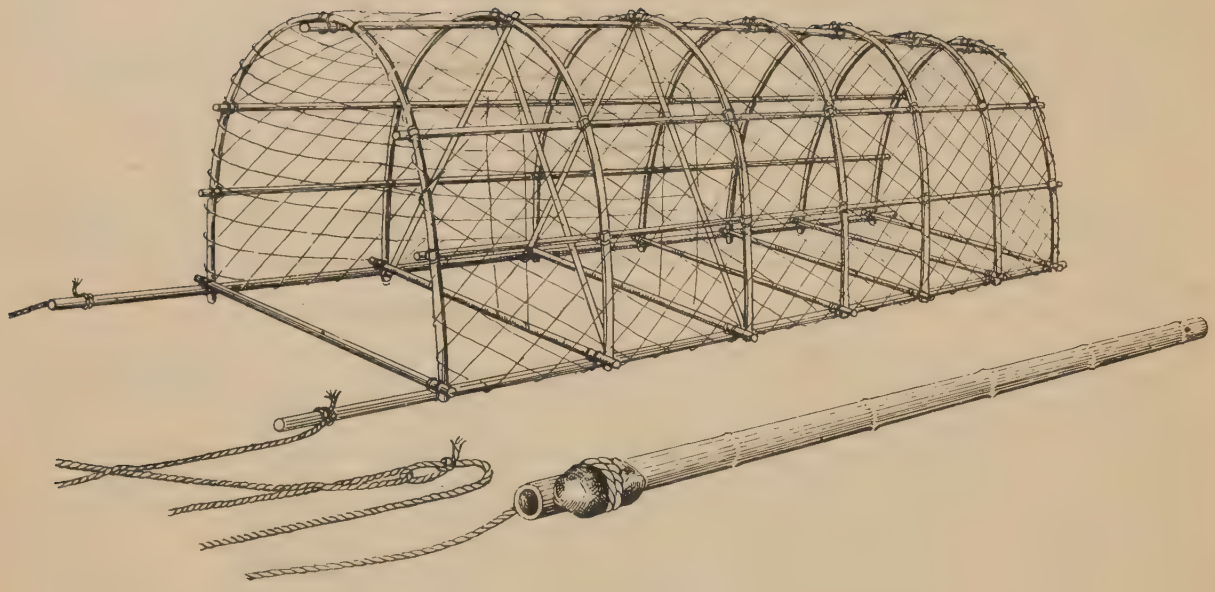


Fig. 7. Hood Shaped Trap

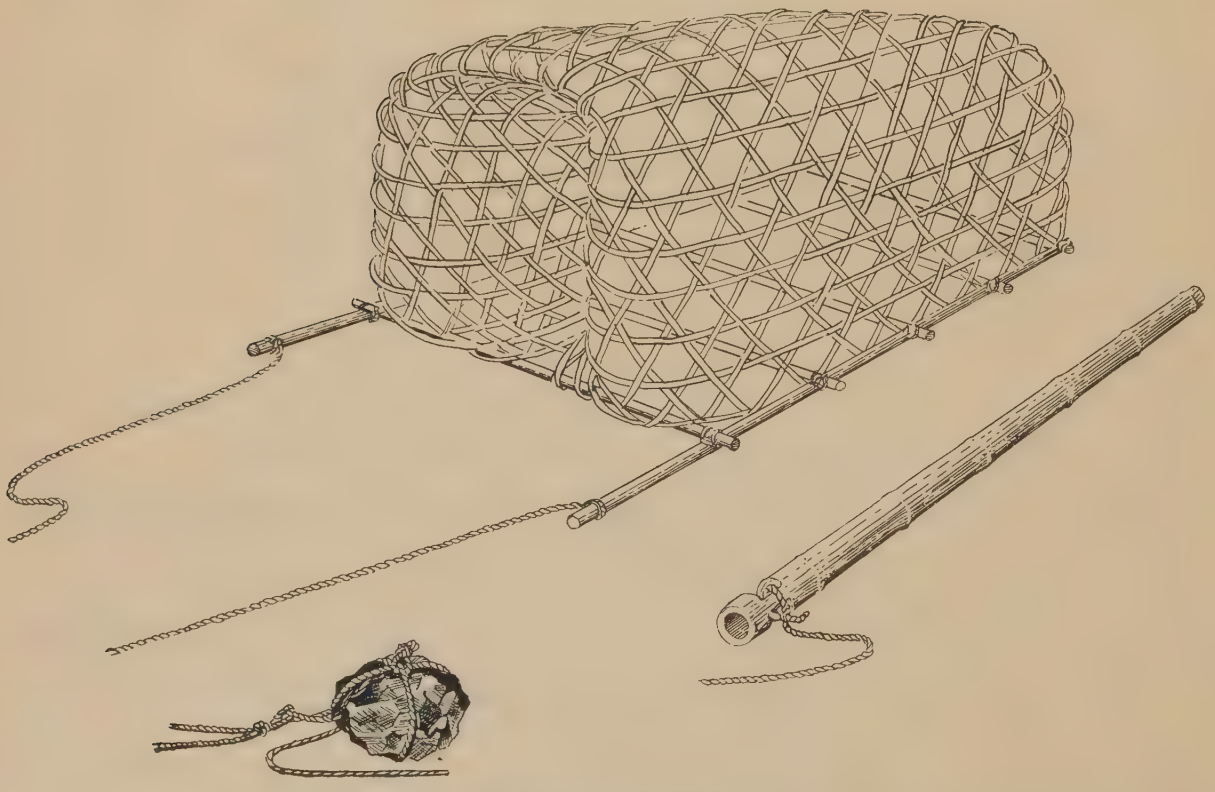


Fig. 8. Rectangular Bamboo Trap

A piece of bamboo about 4—5 meters long with a small stone tied to the big end is used as marker. The bamboo marker is connected with the frame of the trap by 40—50 meters of galvanized wire rope about 1 cm. in diameter. This line serves also as a lift net.

The size of crew and boat used depends on the number of traps to be handled. — Fishing Operation

The traps may be set on any type of sea bottom of 5—8 meters of water. The traps are hauled up at 7—10 day intervals to remove the catch. For larger traps simple winches are used for hauling.

Mostly bottom fish. — Catch

Along the entire coast of the Gulf but especially popular in Smutsakron, Prachuabkirikhant, Rayong, Chantaburi and Chumphorn regions. — Distribution of Gear

41. SAI TANG or BOOBOO PULOH (Rectangular Bamboo Trap)

Figure 8

The trap is more or less rectangular, 1—3 meters long, 1—15 meters broad and 0.7—1 meter high, made of bamboo strips and fixed on a wooden base frame. A bamboo float marker is connected with the trap by a long rattan line. — Construction

Traps are set mostly on coral or rocky beaches, in a depth of 10—20 meters. The traps are hauled up to remove the catch once a day. Sometimes fishermen purposely discard the float marker to avoid traps being stolen. In such a case the traps are set at spots with clear land marks for easy recovery. — Operation

All types of coral reef fish. — Catch

Fishing is done from November to June in Puket Province and the coast adjacent to Malaya. — Distribution of Gear

42. SAINAWN OR LAUB (Cylindrical Bamboo Trap)

Figure 9

Trap cylindrical, 1—1.5 meters in length and 20—60 cm. in diameter at the entrance. The framework of the trap consists of 3 strong rings made of twigs of trees and 5—6 rattan or bamboo rings, on which small bamboo sticks are tied. Two sets of trapping devices are provided; one at the entrance and the other at the middle of the trap. The hind end of the trap is provided with a door for removing catch. Stone weight, bamboo float marker and float line are provided as usual. — Construction

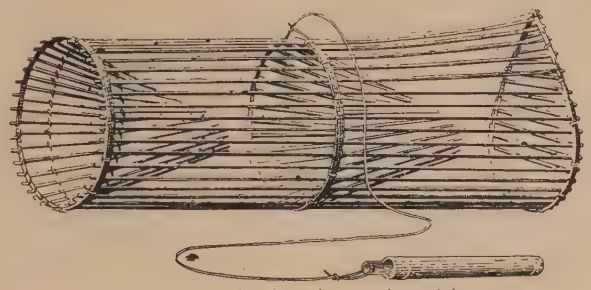


Fig. 9. Cylindrical Bamboo Trap

Fishing is done all year round. Traps are laid in shallow waters near shore as well as in brackish and estuarine areas. Fish flesh is used as bait. — Fishing Operation

All kinds of bottom fish and crab. — Catch

This is considered the most popular trap in Thailand, and is used by fishermen along the entire coast. — Distribution of Gear

43. CHENG LENG (Cone-shaped Bamboo Trap)

Figure 10

The trap is cone-shaped, 1—5 to 2 meters long, made of closely woven bamboo strips. The entrance of the trap is 35—40 cm. in diameter and is provided with a wooden cross bar to which a long rattan line is attached. At the end of the rattan line a bamboo float marker is tied. — Construction

Traps are set on the bottom near to some old Poh or in shallow waters about 1—8 meters deep. Traps are hauled up for removing catch once in every 2—3 days. — Operation

Crabs and Plotosus. — Catch

Fishing is done all year round along the entire coast of Thailand. — Distribution of Gear

Fig. 10. Cone-shaped Bamboo Trap

44. KRUM (Bush Trap)

Construction: Twigs and branches of mangrove trees or shrubs are set in shallow area during low tide into bushes. Fish will be attracted to hide or play around and among the branches. It takes several days (5—7) to attract sufficient fish to the bushes to warrant a harvest.

Fishing Operation: Both long bamboo screen or cotton netting may be employed for catching the fish. The screen is laid down gently around each bush before the tide begins to ebb. The ring is then gradually narrowed down. The bush temporarily removed and the fish inside the screen or net are taken out with scoop nets. The operation may be repeated the whole year round. This type of fishing is quite popular in brackish waters and shallow shore water along both coasts the Gulf.

Catch: The catch consists of a great variety of fishes such as sea bass, plotosus, caranx, groupers etc.

45. POH (Bamboo Stake Trap)

Figure 11, 11a

Construction: There are many variations in size and designs of Poh but fundamentally they follow the same generally pattern and use the same material for construction and similar method of operation.

The principal material used for the trap are wooden poles, bamboo, rattan and galvanized wire.

Fig. 11. Bamboo Stake Trap Poh

The trap consists of one long central wing, one or two pairs of side wings which are directed toward the entrance of a series of one to three compartments.

The framework of the wings and compartments is made of long wooden poles, bamboo poles, bamboo sticks and rattan. The poles used for the wings are about .3—.4 meters longer than the depth of water, while those used for the compartments are .4—.6 meters longer than the depth of water. For each Poh 1,000 to 20,000 bamboo poles are required, depending on the size of compartments and length of wings.

The wings and compartments are completely lined with units of bamboo screens. Each unit measures about 4—7 meters in breadth and 1—2 meters higher than the depth of water. The screens are made of split bamboo, woven and fastened to a bamboo frame with rattan and galvanized wire.

For catching the fish trapped in the last compartment a cotton net somewhat similar to a small purse seine is used. The net is about 30 meters in length and 15—22 meters in height with 1—3 cm. mesh. The head line, ground line, purse line, floats and sinkers are similar to those used for a purse seine net.

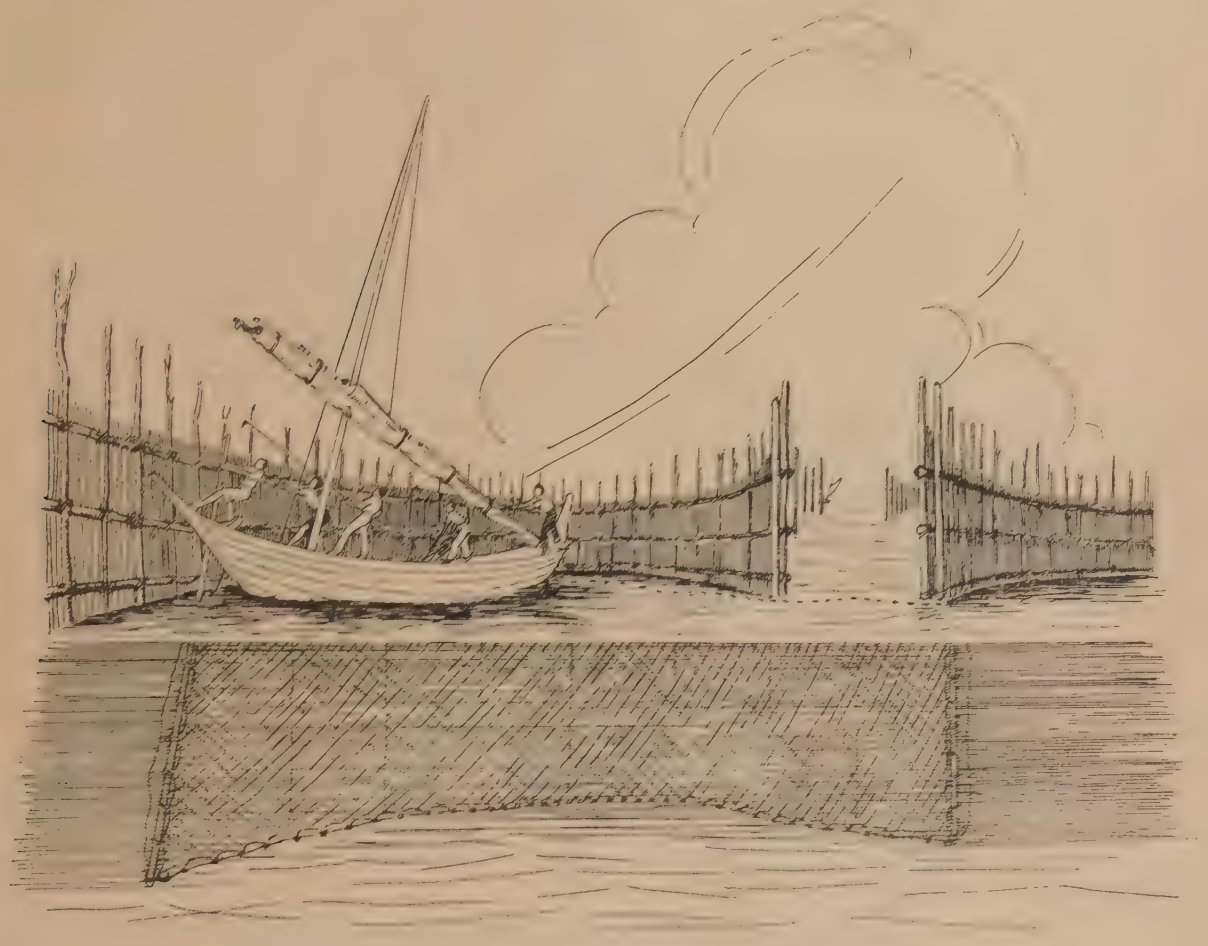


Fig. 11a. Interior View of Catch Chamber of Poh

Boats
Either medium sized sailing boat or motor boats are used.

Fishing Operation
Traps are set in a depth of 6—20 meters, along the shore where the bottom is either mud or mud-sand. Bottoms with stones, and coral formations are not suitable for Poh. The frame work for the trap is laid down during low tide and followed by fixing the bamboo screens to the framework with rattan and galvanized wire.

It takes a long time and much labour to make the screens, and to fix the framework and screening. Once a Poh is constructed its position is fixed and is never changed. During a good fishing seasons the trapped fish are removed during each ebb tide, but during poor fishing seasons the trap is cleared once in every 2 or 3 days.

In removing the trapped fish the net is laid down closely along the inner edge of the last compartment and operated from one strong and long wooden pole set at the corner of the entrance of the compartment.

Catch
Rastrelliger, Cybium, Caranx, all kinds of littoral fish and shrimp.

Fishing Season: Though fishing is done all year round good fishing seasons differ from locality to locality —July to March for the East coast of the Gulf, April to October for the West coast of the Gulf, and all year round for the Indian Ocean coast of Thailand.

Distribution of Gear: Along the entire coast of the Gulf as well as many places on the Indian Ocean coast of Thailand.

46. LAMU, KLENG or LAD (Small Bamboo Stake Trap)

Construction: The framework of the trap is made of a bamboo fence fastened to and strengthened by wooden poles with rattan. It consists of one central wing which is constructed at right angle to the coast and two shorter wings, at 40°—50° to the central wing, leading into two circular shaped compartments.

The bamboo fence is made of units of bamboo screen, each 8—10 meters in length and 5—10 meters in height. 50—200 units of bamboo screens are required for making a complete trap. The poles used for the trap are 5—12 meters in length and 10—15 cm. in diameter, mostly from mangrove trees.

The catch net is similar to a small purse net, about 4—8 meters in length and 3—5 meters in height, made of 2 strands hemp twine with 4-5 cm. mesh. Head and ground ropes are made of 4 strands manila rope 1.5 cm. in diameter. Purse rings are made of lead, 4—5 cm. in diameter and spaced 18 cm. apart. The purse line is made of 4-strand coir rope, 1 cm. in diameter, 10 meters in length. The net is fixed on 6 poles, each 5—6 meters in length.

Fishing Operation: The trap is used in shallow waters up to 7.5 meters deep. It is set at right angles to the shore line with the central wing starting from shallow water and ending with the last compartment in deeper water, which is called the "Heart". The poles are firmly driven into the bottom, and bamboo screens are fastened to them with rattan. The screens of the compartments are further strengthened by top and side poles as shown in the figure. The purse net is introduced each time when the the trap is to be cleared.

Catch: All kinds of littoral fish, especially threadfins and sea bass.

Distribution of Gear Popular along the coast on Indian Ocean side, but are also used occasionally along the coasts of the Gulf.

47. UAN PID AOW or UAN RUNG (Net Trap)

Construction: The trap consists of two wings and a catch compartment. Instead of using bamboo screens, netting is used for the trap. Each unit of netting is 24 meters in length and 1.5 to 2 meters in height, of either cotton or hemp twine with 1—5.7 cm. mesh. For a small trap 8 units of netting are sufficient but for a big trap as many as 20 units are required.

The poles are bamboo 2—2.5 meters in length and 3—4 cm. in diameter. 100—400 poles are used, depending on the size of the trap.

Fishing Operation: The trap is set during low tide in shallow waters close to the shore. The wings are set from the low tide mark and converge into the catch compartment which is set in deeper water. The bamboo poles are firmly set first then the netting fastened to them to the desired height. The fishermen then push the ground edge of the netting into the bottom mud with their feet. The trap is set for 12 hours and when the water is low again the trapped fish is scooped up from the catch compartment with dip net or scoop net.

Catch: Catch consists of various kinds of littoral fish and shrimps, and sharks are occasionally taken.

Distribution of Gear Along the entire coast.

48. FUEAK KARNG KARN or FUEAK RUNG (Bamboo fence trap)

Construction: The bamboo fence trap is constructed on the Poh principle but on a much smaller scale and without using any wooden poles. The trap consists of a pair of long wings which is "V" shaped and directed to 2 successive compartments, the latter of which stands away from the coast in deep water. 30—50 units of screens are required to make one trap. Each unit is 1—2 meters high and 5—7 meters long, made of small bamboo stick, woven and fastened together with rattan. The screens used for the compartments are about 0.5 meter higher than those of the wings.

Fishing Operation: The trap is set during low tide in shallow waters about 1 to 1.5 meters deep, perpendicular to the shore with mud or sand bottom. During low tide the wings are exposed completely and the fish trapped concentrate in the last compartment. The catch is removed by fishermen, employing the locally made "Wooden Horse" (sledge) as means of transport and support when working on muddy shore.

Catch: Small littoral fishes and shrimps.

Distribution of Gear Distributed along the entire coast of Thailand and are operated all year round especially during low water season which varies according to locality.

49. CHUNTHA (Bamboo Screen Net Trap)

Figure 12

Construction

This gear consists of two long wings and a rectangular catch chamber enclosing a bamboo screen net.

The wings are about 80-100 meters in length each, made of long wooden poles spaced about 70—80 cm. apart. The wings are set against current, "V" shaped (with an angle of 75—90 degrees) leading into the catch chamber. The catch chamber is rectangular shaped and constructed of long wooden poles as a frame work and provided with beams and cross-bars, about 25 meters long, 8.5 meters broad and 2—2.5 meters high (depending on the depth of water). Instead of the usual cotton netting a fine bamboo screen netting is used. The bamboo net is made of fine bamboo sticks and rattan woven together, 30—35 meters long and 8.5 meters wide, provided with rattan lift lines and two net setting poles. The cost of constructing one trap ranges from 1500 to 2500 Baht.

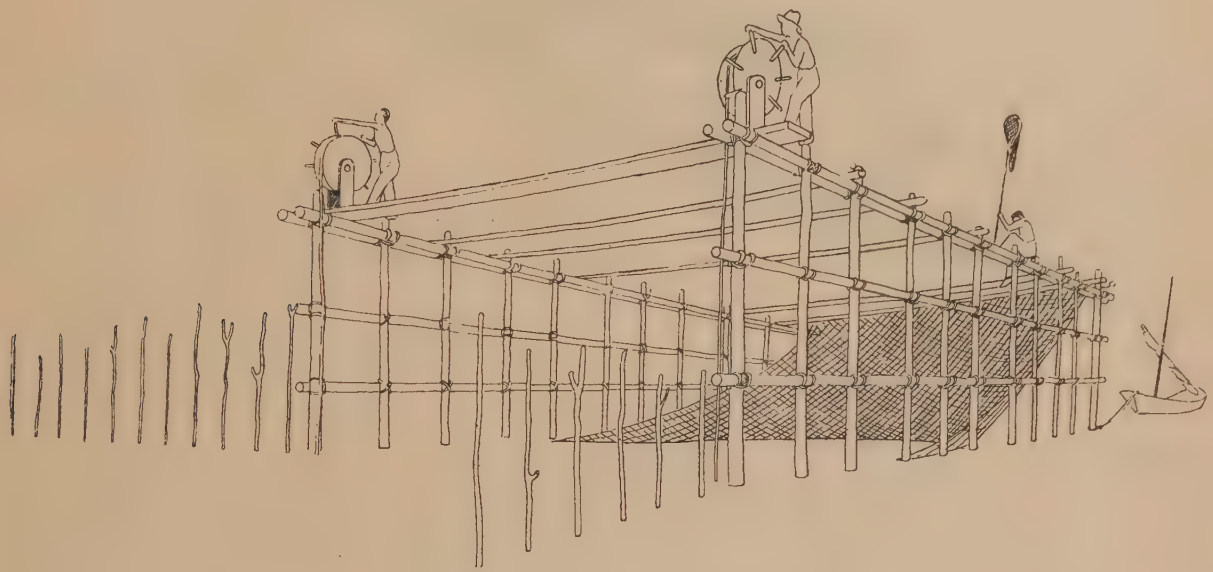


Fig. 12. Bamboo Screen Net Trap

Fishing Operation

The trap is erected in channels between islands where current is usually strong. The wings and catch chambers are constructed during low tide. The hind edge of the bamboo screen net is firmly fastened to the upper hind margin of the catch chamber. When lowered the net covers up the hind wall and floor of the chamber. The rattan lift lines aattched to the front angles of the net are operated by a pair of hand winches fixed on the two front upper angles of the chamber.

During low tide fishermen (4 for shallow water trap and 6 for deeper water trap) go to the trap by sampan or sailing boat. Upon their arrival the bamboo screen is lowered by the help of two wooden net setters. The leading fisherman stations himself on the front edge of the chamber and keeps watch. As soon as he sees fish entering the chamber he signals the two fishermen sitting behind the winch to start hauling the net. The fourth fisherman removes the catch with a long handled dip net. The bamboo screen net is lowered again and the operation repeated until the current stops or water becomes too low.

Catch

Consists of sharks, butter-fish, Dorab, and many other kinds of littoral fishes. The catch is usually divided into 5 portions; the gear owner gets one portion and the rest to the fishermen.

Distribution of Gear

Mostly used in Stull Province along the Indian Ocean coast. Best fishing season for this gear is from February to July.

50. RUA KREAD (Catch-Boat)

Figure 13

Construction

Gear constructed on the principle that while the boat moves along, the fish are frightened and caused to jump into the boat.

The principal parts of the gear consists of a long but narrow sampan, 9—10 meters long and 1 meter wide, provided with a bamboo screen, a cocoanut-leaf fence and a 'kriad' (comb-shaped scare sweeper).

The bamboo screen is 7.2 meters long and 55 cm. high.

The cocoanut-leaf fence consists of a bamboo framework, 7—2 meters long and 40 cm. high, with a single layer of cocoanut leaves knitted between the cross bar.

The scare sweeper consists of a bamboo pole about 8 meters long provided with a row of rattan rods set 10 cm. apart. The length of the rattan rods near the base of the sweeper is 1 meter long, diminishing gradually to ½ meter at the tip of the sweeper.

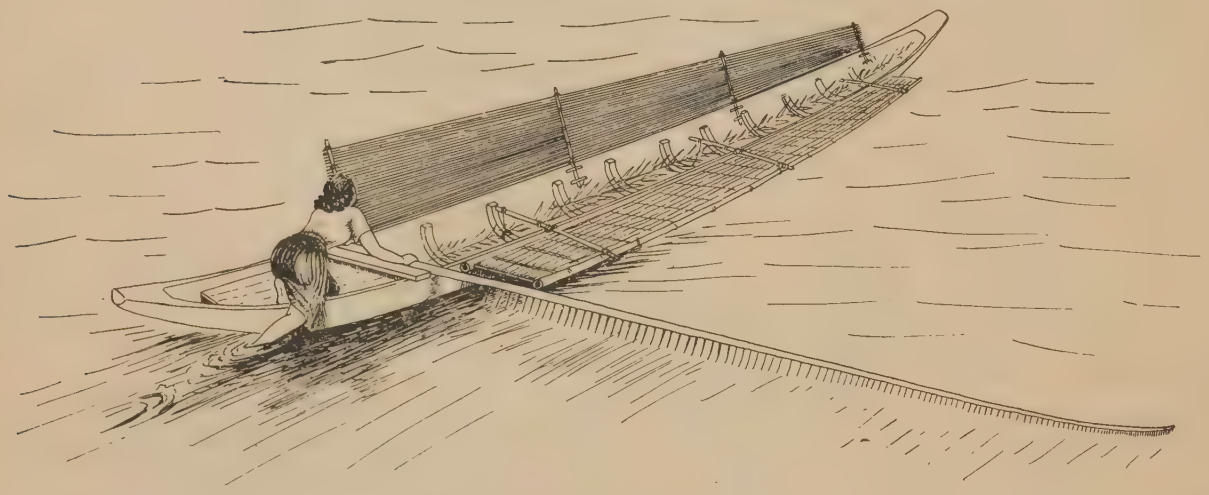


Fig 13. Catch-Boat

Fishing Operation: Operated by one fisherman during dark night only, in shallow waters about 0.2—1 meter deep, close to the sea shore or bank of brackish water areas.

The bamboo screen is erected from one side of the boat while the cocoanut leave fence is hung on the other side of the boat down into the water. The scare sweeper is set at an angle of about 80° degrees to the side of the boat, with the tips of rattan rods barely touching the bottom.

While the boat moves slowly along the bank, many of the fish and shrimps present nearby will be frightened so that they will try to get away by jumping out of the water, resulting in many of them landing themselves inside the catch-boat.

Catch: Many kinds of small shore fish and shrimp.

Distribution of Gear: Krabai Province on the Indian Ocean side and Nakonshritamarasch district on the West coast of the Gulf. Fishing is all year round but August to September is the best season.

51. RUA PHEELAWK (White Board Catch-boat)

Construction: A white painted wooden board 4—6 meters long and 60 cm. high is used in place of the cocoanut leaves fence, and ramie or cotton netting is used for the screen. No scare sweeper is employed.

Fishing Operation: This gear is operated only in daytime. The fisherman rocks the boat violently while he rows it along the shore or bank of shallow brackish water areas. The motion and sight of the white shinny board are effective in causing fish and shrimp to jump.

Catch: Mullet, sea bass, shrimps etc.

Distribution of Gear: Throughout entire Thailand. Used all year round.

52. YAW NGAT (Simple Catch-boat)

Figure 14

Construction: A very simple type of Catch-boat. Only a cotton or ramie screen is used, erected on one side of the boat.

Fishing Operation: Operated by two fishermen. Fishing is done at night in very shallow waters along the banks. The fishermen while rowing the boat slowly repeatedly beat the water with their oars to frighten the fish.

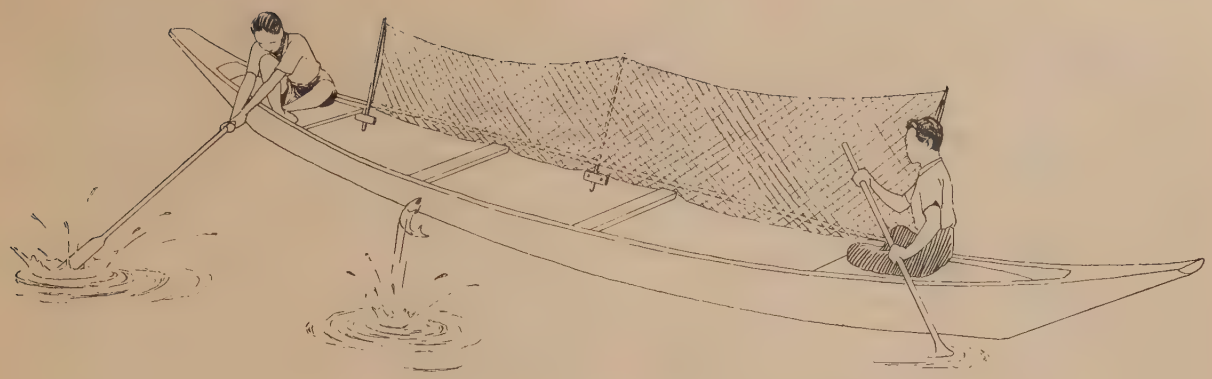


Fig. 14. Simple Catch-Boat

All kinds of shore fish and shrimps. — Catch
Used all year round in Krabi Province on the Indian Ocean side. — Distribution of Gear

53. CHAMUAK (Harpoons)

Many kinds of harpoons are used by coastal fishermen. A typical one consists of a spear head, a handle and a harpoon line. — Construction

The spear head is made of iron, about 16 cm. in length, with a sharp prong and a sharp barb.

The base of the spear head is provided with a metal ring to which a long harpoon line is attached. The handle is made of bamboo, about 2 meters in length.

Two fishermen operate as a team from a small sampan; one rows the boat and the other manages the harpoon. Fishing is done in day time in clear shallow waters all year round throughout the entire coast of Thailand. — Fishing Operation

54. KAW LUANGPOO (Crab hook)

The hook is made of small iron rod or coarse galvanized wire, about 60 cm. in length and 0.5 cm. in diameter. The basal position of the hook is firmly fastened to a wooden handle of about 80 cm. long.

This gear is especially handy for catching crabs (*Scylla serrata*) in mangroves and among rocks. The hook is inserted into the crab hole and the crab is pulled out gradually.

11

AN EXPERIMENT IN FISH SALTING

by

J. Westenberg*

ABSTRACT.

As a result of improvements in the production system of the Kalianget Saltworks (East Madura), the fish preserving home industry of East Java and Madura had to deal with several changes in the properties of the salt, e.g. its chemical composition. In this experiment the influence of the more important natural mixtures on the quality of salted and dried fish was tested by their component ions separately, viz. Mg^{++}, Ca^{++} and SO_4^{--}. For this purpose $MgCl_2$, $CaCl_2$ and $Na\ SO_4$ were added in various quantities to the salt. Pure sodium chloride yielded the best product.

During the last few years prior to the war, several details of the production system of the Kalianget saltworks (East Madura) underwent improvement by introduction of a more careful control of the process of crystallization, and by adoption of the so-called Portugese method of gathering the salt.

* In charge of the Service of Sea Fisheries, Poatere, Makassar, Indonesia.

In the modern Madura production, the seawater is made to circulate slowly over a wide area in a series of shallow reservoirs whilst the depth of the water is kept constant at about 5 cm. As evaporation takes place, the greater part of the calcium sulphate precipitates at densities within the range between 16° and 20° Baumé. The brine is concentrated to a density of 26° Baumé, and then transferred to the crystallization beds, where it is kept at a constant depth of 2 cm. On further evaporation, crystallization of sodium chloride will set in. The density of the brine should now be carefully watched to prevent it from exceeding 29° Baumé, lest magnesium salts would also precipitate. When this density has been reached, the residual brine is drained off. Formerly this process was not so closely followed, but since the densities of the brines were kept under control, the product has gained in chemical purity.

The crystallization beds require a thorough preparation before coming into production. After carefully flattening and hardening the soil with a roller, the brine is allowed to flow in and an initial crystallization of several weeks follows. In the Portuguese method, the first salt crust is then flattened, and continued crystallization makes the initial crystals grow together. This is repeated several times, so as to form one single impermeable layer, after which production proper is started. Subsequent deposits of crystals can be scraped off and piled up for transport without any contamination with soil. By this process the salt is pure white, whereas formerly the crystals were simply raked off the soil, which resulted in a more or less grayish, or sometimes brownish, coloration.

In the new production system, the time interval between two successive harvests has been reduced from three or four to two weeks, so that the product is less coarse than before. Apart from these changes, mechanically crushed salt had been furnished to fish-salters to be used without being pounded by hand.

As a result, the fish preserving home industry of East Java and Madura has had to deal with changes in chemical composition, colour and grain of the salt. These conditions have raised quite a lot of contradictory comment on pretended drawbacks and profits, and therefore we decided to investigate the effect of the factors in question on various methods of fish preservation. The outbreak of World War II prevented the complete elaboration of this programme, but opportunity still permitted a test of the influence of the natural mixtures of the salt on the quality of salted and dried fish. The finished product was judged according to criteria in common use in the trade, since only these are decisive in economy. In this final stage of the experiment, the Borsumij Trading Company kindly offered its help by placing at our disposal its Chinese fish expert, Mr. Tan Ek Sien, who proved to be a keen connoisseur. Chemical analysis was beyond the scope of our investigation, since the concept of quality has not yet reached a stage of chemical definition for the product under consideration.

In the salting of fish, the salt dissolves into the body liquids of the fish and soon forms a pickle. Thus it will exert its further action in a dissolved state and for this reason the action of the most common natural mixtures, viz. $MgCl_2$, $MgSO_4$ and $CaSO_4$, was tested by their component ions separately. Each of the kations, viz. Mg^{++} and Ca^{++}, was added in the form of its chloride, and the anion SO_4 were added separately in quantities of 1/3, 1 and 3% to the salt used for the different lots, whereas one lot was treated without any of these additions.

In order to demonstrate the differences as clearly as possible, the salt used for this experiment should be as pure as possible. For this purpose, the late Ir. Ph. Jordaan, at the time Director of the Government Saltworks at Kalianget, Madura, kindly placed at our disposal a quantity of re-crystallized salt of high purity, containing no detectable quantity of magnesium salts, and only traces of calcium sulphate (within the range of 0.02—0.03%). Although this salt had a finer grain than that normally used for salting fish, it was still quite suitable for our purpose.

The range thus realized in the experiment fully covered the occurrence of natural mixtures in the salt used in commercial fish preservation. Combined additions of $MgCl_2$, $CaCl_2$ and Na_2SO_4 were not included in the experiment.

Since, for our purpose, it was especially desirable to work up the fish as fresh as possible, a fishing village nearest to the fishing grounds was looked for, and thus we came to choose Sangkapura, Bawean, as our working site. Here, the fish was caught at daybreak and landed before 9 a.m. At the time of our experiment (August 1941) supplies were mixed, and for the sake of a quick treatment, we refrained from sorting the catch, which consisted mainly of three species, viz. Layang (*Decapterus russelli* Rüpp.), Tembang (*Clupea fimbriata* (C.V.), and Lemuru (*Clupea leiogaster* (C.V.)).

In treating the fish we closely followed local practice. In mass production, here, the fish is salted in the round, the average proportion being one part of salt to four parts in weight of fish. The fish is kept under moderate pressure, so that it is soon covered by the originating pickle. Next morning, the fish is washed with fresh water from a pit, then spread out on bamboo racks and dried in the sun, which takes two to four days, according to weather

conditions and size of the fish. The finished product is finally packed in baskets and is then ready for sale.

For our experiments, 10 portions of fresh fish of 40 kg. and 10 portions pure salt of 10 kg. each, were weighed out. Of each of the compounds $MgCl_2$, $CaCl_2$ and Na_2SO_4, quantities of 33 gr., 100 gr. and 300 gr. of each had been put aside beforehand (making nine portions in all).

The mixing of the fish and the salt was done by hand in a wooden salting box; nine of the ten lots with addition of the weighed quantities of magnesium or calcium chloride or sodium sulphate, and one lot as a blank test.

After each blending, fish and salt were transferred into a clean tub of teak wood, and the salting box was carefully rinsed with freshwater and dried with a clean rag. All of the ten tubs were brand new in order that none of the extracting salt remains of former use could cloud the results. This precaution was especially urgent in the present study of different action by natural salt mixtures.

A cover of wicker bamboo was placed on top of the fish and weighted with a stone heavy enough to keep the fish covered with pickle. Next morning the fish was removed from the tubs, washed and spread out to dry in the usual way. While rinsing the fish, the lemuru showed the most apparent signs of autolysis, viz. a soft flesh and some open bellies. Furthermore it appeared that in all of the three species, the scales were washed off less easily in the calcium treated lots.

After drying, a random sample was taken from each lot. The samples were judged by Mr. Tak Ek Sien, employing the usual criteria of general appearance, odour and taste. It goes without saying that he had not been informed of details of the preparations.

The fish that had been treated with pure salt only was repeatedly pointed out as the best, especially because of attractive odour and taste.

The $MgCl_2$ treated fish had a firmer texture and was lighter in colour. It was still judged rather favourably, but a higher magnesium concentration had given a bitter edge to the salty taste.

The $CaCl_2$ treated fish had a less favourable appearance, due to adhering scales, and a dull white-looking flesh. Also referring to taste and smell, these samples were less attractive than the product prepared with pure salt only.

The Na_2SO_4 treated fish was appreciated least of all, because of its unhealthy taste and smell.

The differences described here were most distinct in the lots of the 3% series. In the 1/3% series, the differences were only just discernible by an expert, whereas the 1% series was intermediary.

12

FISHERY PRODUCTS OF INDOCHINA.

A COMPILATION OF LITERATURE UP TO THE JAPANESE INVASION

by

J. Westenberg.*

ABSTRACT

This paper presents a compilation of data on fishery products of Indo-China, drawn from literature, chiefly of French publication.

The first section gathers together descriptions of methods of processing, involving techniques of salting and drying, and conversion into pastes, condiments and oils.

The second section summarises results of chemical analyses, chiefly of nuoc-mam.

The third section summarises the results of attempts to westernise these methods.

INTRODUCTION

Having become aware of the great economic importance and industrial prospects of the native fishery industry of Indochina, the French government has carried out investigations that appear to be unknown except in the French literature. Since they deal with facts that are of importance for the more general problems of fish preservation in the tropics, it might be useful to discuss them in a journal with a wide circulation.

* In-charge of the Service of Sea Fisheries, Paotere- Makassar, Indonesia.

The most profitable fisheries of Indochina are found along the coasts of Annam and Cochinchina and on the lakes and rivers of Cambodia, as may be seen in fig. 1; the black spots indicate the fishing centres.

The preliminary investigations concern the native fishery products only. Subsequently attempts were made to build up a modern industry by introducing western principles in the procedures.

From a commercial point of view, major importance is attached to the salted and dried fish industry of Cambodia, which contributes an appreciable share to the exportation of the country.

In addition to the usual methods of preservation, applied all over the world, such as salting, drying and smoking, other processes are utilized in the country, yielding products which are typical for this part of the world. A number of these condiments in the nature of pastes are indicated by the general designation mam. According to the material used, and to local differences in the preparation, several varieties are distinguishable, for instance pra-hoc from Cambodia and Siam, phaak or mam-chao from Cambodia, pa-dec from Laos and mam-tom from Cochinchina and Annam.

Further there are liquid condiments, among which nuoc-mam from the coasts of Indochina and Siam is the most important. These products do not constitute a principle food, but serve as a relish to the meals which consist chiefly of rice, vegetables, salted fish, dried shrimps and various soups. Nuoc-mam is widely used, but locally pra-hoc, phaak, pa-dec or mam-tom rank first. The flavour of all of these condiments is highly appreciated by the natives but seems to be unpalatable to Europeans.

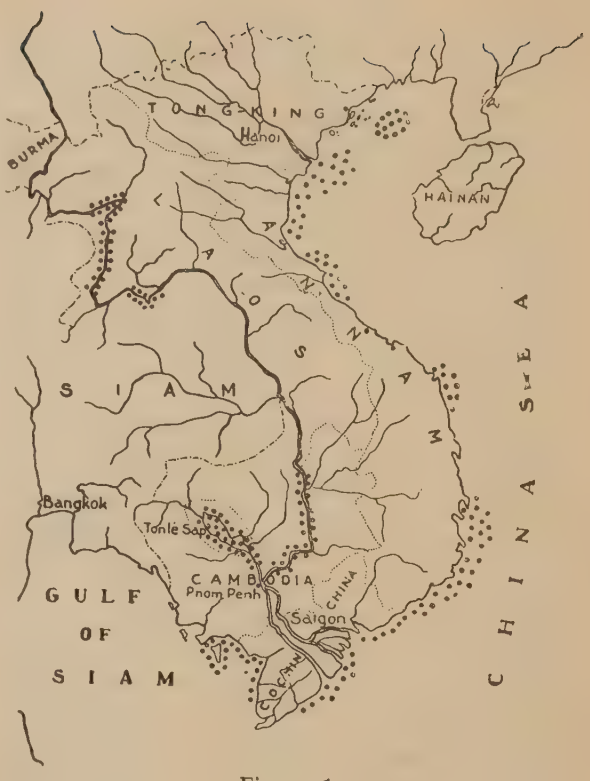


Figure 1.

Fish oil is also produced in considerable quantity, sometimes as a major industry or often as a byproduct of the manufacture of dried fish and nuoc-mam.

SECTION I FISHERY PRODUCTS

A. Salted, dried, smoked and cooked fish and shrimps.

Salted fish.

The salting of fish, without subsequent drying is sometimes practised for local demand, especially in Cambodia, but never in large quantity for exportation (Pétillot, 1911; Gruvel, 1925).

Usually medium size fish are used for the procedure; head, scales and viscera are removed and the fish split open, according to the local custom, depending on traditions and the species used. The dressed fish are then placed in jars with alternate layers of salt. Information on the quantities used appear not to be available in the present literature. The jars are completely filled and covered with a mat of twisted bamboo, weighed down with stones. In this way the fish may be kept as a family store to be used when needed.

Along the coast of Siam, the same procedure is applied to *Scomber neglectus* C. V. Prior to the preservation, the fish are eviscerated without opening the bellies; entrails and gills are skilfully pulled out in a single movement. The salting is carried out in large concrete tanks, in which the fish is kept under pressure. The half wet product is exported in wooden cases and in Java it is well known as pedah-kembung.

A special procedure of fish salting has been reported from Siam, in which roasted and pounded rice or rice bran is added; the preparation is known as pla-ra (pla = fish; ra = awful smell). The freshwater fish pla-kadi (*Trichopodus sp.*) and pla-soi (*Cirrhinus sp.*) are headed, scaled, gutted and washed, and then thoroughly mixed with fine salt, transferred into a jar and kept under pressure for 1 to 3 months. After this period the pickle is rinsed out and the fish is mixed with roasted and pounded rice or with rice bran, and a small amount of fine salt. The mixture is then put back into the jar

and left to ferment for 6 to 12 months. According to the addition either of roasted rice or of rice bran, the product is known as pla-ra-kao-kuo (kao = rice; kuo = roasted) or pla-ra-ram (ram = rice bran). The roasted rice is added in a proportion of 1 to 40 in volume, and the rice bran in a proportion of 1 to 20. The product is prepared either for home use or for sale.

The application of roasted rice or maize is also practiced in South Borneo. When preparing their so-called wadi, the dayaks along the Barito salt their (fresh-water) fish with the addition of the roasted ingredient. The product is stored in tightly sealed earthenware pots, and is kept for family use.

The addition of cooked rice is known among the dayaks along the Barito and along the Kapuas (West Borneo). The product is known as pekasam, and is stored in sealed pots.

A similar preparation with cooked glutinous rice instead, is reported from the Kapuas-region.

Salted and dried fish.

The manufacture of salted and dried fish is an active industry, especially on the lakes and rivers of Cambodia, where it has been studied recently by Chevey and Le Poulain (1939).

Preparatory to the procedure, the heads are severed as soon as the fresh catch is brought in. The fish is then held for 12 to 16 hours is an open work bamboo container, floating in the lake. This treatment brings about a slight disintegration which is said to yield the desired bleached and high flavoured product. In large scale production, the heads are usually discarded in the water, but in the smaller business, they are often kept apart for oil winning. Occasionally, the heads of Trey-pra (*Clarias sp. div.*) are split open and smoked as food for the coolies.

Baskets of fish are removed from the receptacle, and handed over to the women who accomplish the dressing by pulling out the entrails and making a slit from head to tail, according to custom established for the different kinds of fish, and depending on local tradition. Certain species are scaled with a crude brush before being split and eviscerated.

After a thorough washing in tubs, in which the water is renewed several times, the larger fish of first quality are salted flat, both sides of the flesh being treated with salt. The fish then remain under slight pressure in the salting vats, until they are "struck through", which takes 12 hours for the larger species, and 6 to 9 hours for young Trey-pra. After a second washing they are transferred to the drying platforms. As a rule one part of salt is used to obtain two parts of dried fish, proportionate to weight. For oily species such as Ca-su (*Pseudosciaena sp.*) more salt is used, namely 1½ parts of salt to 2 parts of dried Ca-su. Other deviations from the usual proportion occur according to weather, and to size, condition and destination of the fish.

The second quality and small fish are brine salted for a period of 12 hours and then spread out directly on the drying platforms, without being washed again.

The drying of the fish requires 36 to 48 hours of full sunshine. From time to time the fish is turned in order to ensure equal desiccation. The women who attend to the drying also watch for maggots which occur especially during rainy weather. These invaders are removed and the affected spots are rubbed with salt.

The line of the whole industry has been outlined in the following scheme (Chevey & Le Poulain, 1939):

In the preparation of dried fish, the average loss in weight is estimated at 75%; waste 30% and evaporation 45% (Lebas, 1925).

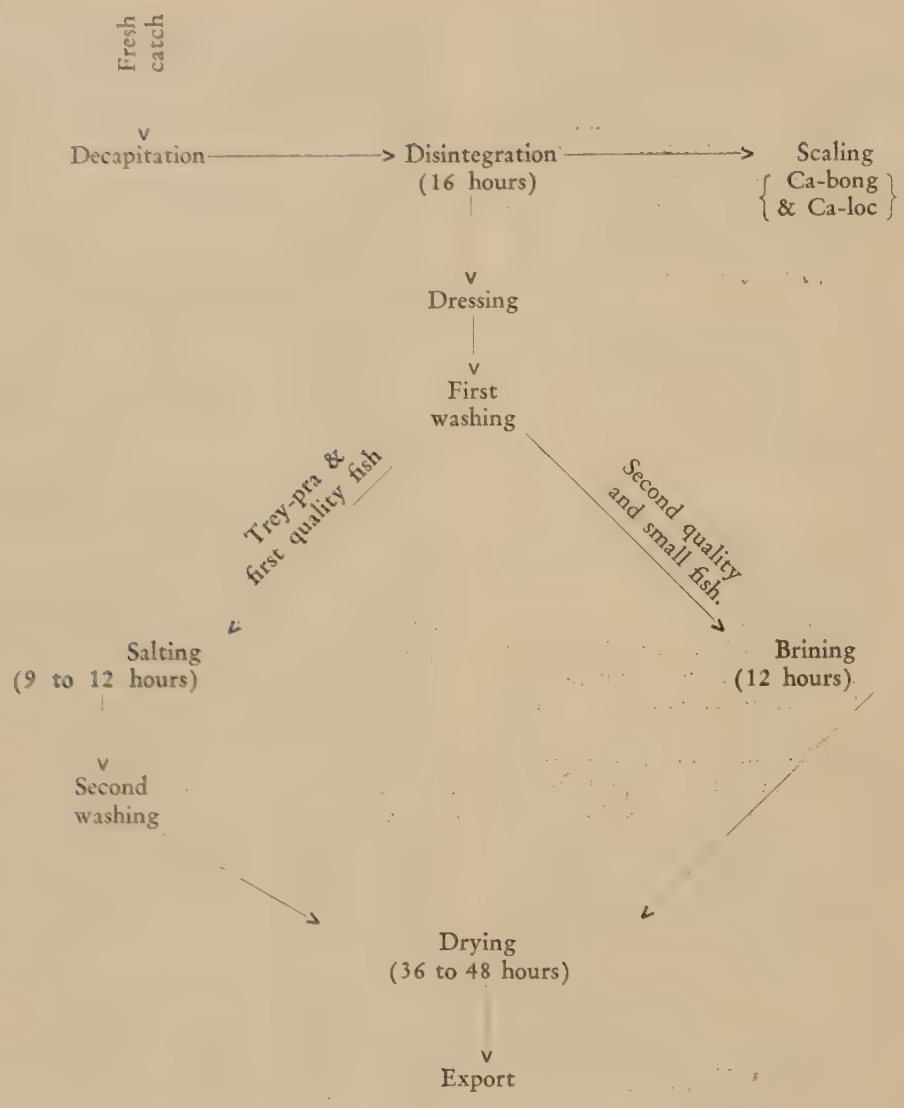
The finished product is baled either in matting or in bamboo baskets, and in this form more than 20,000 tons are exported annually from Saigon, at prices roughly averaging about 12 piasters per 100kg.[1] during the years 1919—1922 (Gruvel, 1925). During later years the market has shown considerable fluctuations (Chevey & Le Poulain, 1940). Here, as nearly everywhere in the Far East, the trade in dried fish is in the hands of Chinese. A major part of the commercial trade is directed to Singapore, from where a considerable exportation is maintained to Java (Maron, 1939). In the Java trade, dried *Trichopodus trichopterus* (Pall.) has a special reputation, and is known under its Malayan name sepat siam. Shortly before the war, attempts were made to conduct the exportation direct to Java.

A variation of the above procedure is reported by Chevey (1931, p.31-32) and by Krempf (1934, p.3695). Here, immediately after the catch, the fish are placed in a pickle which may not be renewed during the whole season, and after 4 to 6 days the fish are exposed to the sun to dry.

In still other cases, the fish remain in the pickle till they are sold. The required quantity is then washed and dried. This treatment really constitutes a variation of the simple salting of fish, as described in the first part of this section.

Another important centre of production of dried fish is the Gulf of Tonkin (Guilbert, 1916). The fish intended for China is for the greater part already cured and dried on board the junks. The fish for consumption in Indochina is landed and

[1] In 1922 one piaster equalled about 0.54 U.S. dollar.
" 1928 " " " " 0.50 " "
" 1938 " " " " 0.29 " "



then either salted or brined and then dried. The fish is treated in similar ways as on the lakes of Cambodia. The larger species are cut open from the back, eviscerated and washed with sea water, piled up with alternate layers of salt in tubs or pots and kept under pressure for 7 days. Then the fish is dried in the sun for 3 days. The quantity of salt used amounts to one half of the fresh weight of the fish. 100 kg. of fresh yield 70 kg. of the dried product. For brining the dressed fish is soaked in brine for 12 hours and then dried in the sun for 3 to 4 days; the quantity of salt is about one quarter of the weight of the fish.

Breymann (1902) mentions that the drying of fish for home use without previous salting is practised in Cochinchina, where the sun is hot enough to desiccate the product before putrefaction can set in.

An interesting variation is reported from Tonkin (Chevey & Lemasson, 1937, p.182). Fresh-water fish are eviscerated and then placed in alternate layers with salt, the average proportion being 2 kgs of salt to 10 kgs of fish. Thus the fish are left for a period, which varies from 1 to 4 days according to the length of time it is desired to hold the fish. They are then sprinkled with tinh (roasted and pulverised rice), and exposed to the sun until completely dry.

Fishermen of Indochina have, just as anywhere else, a preference for certain portions of the fish,

which they reserve for family consumption (Petillot, 1911; Gruvel, 1925). These include, for example the two dorsal muscular masses found immediately behind the skull of Trey-pra, which they call touv, and also komphlien, which is taken immediately behind the jaws from Trey-ras and Trey-chhdor (an Ophiocephalid fish). These pieces, measuring 3 to 5 cm. in diameter, are slightly brined and then dried. After immersion in the pickle for 5 minutes, they are strung on split bamboos and placed in the sun.

Smoked fish.

On the shores of certain bodies of water, in particular the Tonle Sap a small quantity of fish is smoked (Petillot, 1911; Gruvel, 1925 Lebas, 1925).

The fish destined for smoking is not decapitated but only scaled and eviscerated by opening the belly. No salt is used in this preparation. The product is kept for local use (Lebas, 1925).

Groups of five or six are skewered by the heads on a split bamboo, some space being left between, and the tails are tied together. Then they are placed on three superposed and slightly inclined bamboo racks under which a smoky wood fire is maintained day and night. In order to obtain a uniform product, the position of the fish is changed regularly.

Brine cooked fish.

On the coast of Annam, Ca-moi (*Dorosoma nasus* Bloch, a Clupeid fish) is cooked in brine for oil winning (Marcelet, 1929).

Alternately a layer of fish and a layer of salt are placed in petroleum tins; subsequently a 10% brine is poured over it. After 5 hours boiling, the liquid is poured off, and the containers with cooked fish are sent to Cochinchina, where it is considered a choice food.

In Java, Madura and Bawean (East Indies), seafish are prepared in a similar way in earthernware pots and petroleum tins. This product is known as pindang, and has locally gained considerable importance in East Java.

Air bladders.

The air-bladders of fish, especially developed in Sciaenids, Silurids and Cyprinids, constitute a valuable byproduct. After careful removal, and through washing, they are opened and dried flat in the sun during a half or a whole day. Guilbert (1916) has reported from the Gulf of Tonkin that drying is sometimes practised over an open fire with aromatic herbs.

The first quality air-bladders are used in Chinese and native cookery. The coarser quality product is destined for the manufacture of fish glue.

Shark fins.

Several species of sharks are captured for the sake of the fins, which are classed in several groups of different values depending on colour, size and variety.

In preparing fins for the market, they are cut from the shark and dried in the sun or over an open fire (Guilbert, 1916). This product is particularly used by the Chinese for the making of soup, and almost the whole catch is exported to China (Gruvel, 1925).

Tom-kho (brine cooked and dried shrimps).

The product is especially esteemed by the Chinese (Petillot, 1911). For the preparation, shrimps are cooked in saturated brine, and exposed to the sun for several days, until they are bone dry. Then they are threshed with flexible bamboo sticks, to separate the flesh from the husk, after which the shells are winnowed.

B. Pastes (Mams)

Pra-hoc (fish paste from Cambodia).

The data with regard to the preparation of pra-hoc are rather varied (Bremond, 1919; Le Poulain, 1938), possibly due to different local circumstances, and it is difficult to combine the descriptions into one compilation. We will quote below the statements of these authors separately.

Le Poulain relates the following: Pra-hoc, a national condiment of the Cambodians, is the product of an industry, which is purely a home industry, practised only in the months of December and January in connection with annual festivals, which play an important part in native life. Every year, at the time of the King's birthday, the peasants leave their villages and go in ox-carts to certain centres in the neighbourhood of the capital, Phnom Penh, where encampments are set up. During their stay they exchange rice, brought along for this purpose, for fish from the Tonlé Sap. This exchange is made only at certain periods of full moon, which is considered essential for the success of the first operation in the preparation of Pra-hoc.

Le Poulain describes two methods for the preparation of pra-hoc. For the first method small Cyprinid species are used. These species are collectively denoted as Trey-changvar, and belong to Rasbora and allied genera. Accordingly, the product is called prahoc trey changvar.

For the second method, which is less usual, only one variety is used, that is either

Trey-chhdor=Ca-bong=*Ophiocephalus micropeltes* C.V.
Trey-ras =Ca-loc =*Ophiocephalus striatus Bl.*
(Ophiocephalids)

Trey-kahek =Ca-ct =*Labeo chrysophekadoin* Bl.
(Cyprinid)

or occasionally other species. The larger fish are collectively denoted as Trey-tom, and accordingly the product is called prahoc-trey-tom.

In a subsequent paper, Le Poulain (1939) mentions many other Cambodian and Annamite names of fishes that are used for pra-hoc making, but since taxonomic designations are incomplete, it would be rather confusing to cite these.

In the first method the Trey-changvar is beheaded and eviscerated and is then, without being scaled, put into a wicker basket, called cheal. The heads are either thrown away or may be preserved for the extraction of oil. The fish, which half fill the cheal, are trampled upon in much the same manner as grapes in a winepress. The purpose of this treatment is to scale the fish by friction and to empty the entrails by compressing them. Then the fish are washed by plunging the cheal into a river or pool. For half an hour the fish are stirred by hand till they are completely scaled. Then they are again pressed in the cheal in order to remove the water. The upper part of the cheal is covered with banana leaves, upon which a weight (e.g. heavy stones) is placed in order to compress the fish. They are left under pressure for 24 hours.

Next day the fish are taken out of the cheal and, for about a half hour they are mixed with coarse salt. About 2 to 3 kgs. of salt are needed for 20 to 30 kgs. of fish. When the fish are well impregnated with salt they are spread out on matting in the sun for 24 hours. Then the fish, salted and dried, are put back into the cheal, care being taken to leave as little space between as possible. The first process of preparation for the manufacture of pra-hoc, carried out in the fishing places, is now finished. The cheals, filled with the prepared fish, take the place of the traded rice in the ox-carts and are transported to the villages. Upon arrival the villagers take the cheals from the carts and the process of pounding begins. The fish, prepared as described in the foregoing, are placed in small quantities in heavy wooden mortars, operated either by hand or by foot.

The pounded fish form a salted paste which the Cambodian tastes to judge whether it is salt enough. The pounding takes about 20 minutes. The paste is then packed in earthen jars of 1 picul (= 60 kg.) These jars are placed in the sun and left open in the day-time; in the evening they are closed to keep out the maggots. As seasoning takes place gradually a pickle appears on top of the paste. This liquid is removed every day until no more collects; it is kept aside, for the Cambodians use it as nuoc-man and call it teuk-prahoc. This process may last a month. When there is no pickle left, the preparation of pra-hoc is finished and the condiment is ready for immediate consumption. According to Le Poulain, 3 piculs of Trey-changvar yield 1 picul pra-hoc. It is used principally in the preparation of soups, the many varieties of which play an important part in Cambodian cooking.

Manufacture by the second method is more aristocratic, since it is more expensive. Only one variety of fish is used, either Ca-bong, Ca-loc, Ca-ket or Trey-kahek, but never the four of them together. This product is not on the market and is consumed by the elite of Cambodia.

The fish are headed, scaled and gutted, the bones are removed, and only the flesh is preserved. This is put into pails of water and left for three days and three nights; then, as in the first method of preparation, the fish are placed in cheals to drain, and are pressed out. The fish are not trampled upon, as they have already been scaled and eviscerated. The process of salting is the same as in the first method, but the fish are not pounded, and the morsels of flesh are carefully placed in the jars, the whole being well compressed by hand.

Bremond (1918 & 1919) gives a less extensive description of the preparation of pra-hoc. For the first quality product, according to this author the following fish are used:

Trey-pra = *Clarias* (Silurid)
Trey-ras = *Ophiocephalus striatus* Bl. (Ophiocephalid)
Trey-pruol = *Cirrhinus microlepis Sauvage* (= *Labeo pruol* Tirant) (Cyprinid)
Trey-andong = *Synbranchus bengalensis* Mc. Clelland (Cobitid)

For pra-hoc intended for consumption in Siam, Trey-andong is used exclusively.

The dressing of the fish is begun by removing the scales. The heads and viscera, with the exception of livers, are then cut away. The gutted fish are sliced and soaked in fresh water overnight. Next morning they are taken out of the water and dried in the sun for the whole day. At about five o'clock in the afternoon they are mixed with salt and placed in a basket, to allow the pickle to drain. Next day the fish, which have been reduced to a paste, are once more exposed to the sun and in the evening salted again. The mass is then stored in a pot and during the first three days the collecting pickle is poured off and may be used as nuoc-mam. Finally the pot is sealed with a wooden cover or a piece of cloth, tied with string and covered with a pulp of wet wood ashes. Pra-hoc of first quality is ready for use after two to three months and will keep for two years.

The analysis of a sample of this product revealed a salt content of 17%.

For pra-hoc of second quality, little fish (Cyprinids) are squeezed and pressed under water and in this way divested of their scales and viscera. They are then washed and soaked in fresh water overnight, mixed with salt and placed in pots to season for one month. Pra-hoc thus prepared is consumed by the lower classes.

According to Le Poulain (1939, priv. comm.) first quality pra-hoc is sold at a rate of 0.20—0.30 piasters per kg. and 12—17 piasters per picul (of 60 kg.); second quality pra-hoc 0.15—0.20 piasters per kg. and 9—12 piasters per picul.

An inferior quality pra-hoc is occasionally produced by the Annamites and destined for Cambodian consumption. The Annamites manufacture this product from small fish, Trey-real or Ca-linh (*Thynnichthys sp.* and *Albulichthys sp.*—Cyprinids), when bad weather prevents the use of nets. In addition when the catch can not be returned in time because of unfavourable winds, the stale fish may still be utilised for this production. The coolie fishermen manufacture with these fish a prahoc of inferior quality; they use principally Ca-son (*Ambassis sp.*—Percoid) which is placed in brine overnight. Next morning the fish are taken out and dried in the sun for two days. Finally they are pounded with salt and stored in a jar for ten days. The proportion of salt to fish is about 15%.

There exists on the other hand a product manufactured by the Annamite fishermen and sold to the Cambodians, known as prahoc-youn. They utilise for this the residue of the great fisheries. The proportion of salt is usually less than in the preparation of the Cambodian product, which makes a modification in the odour.

Paak or mam-chao. (Cambodian fish paste, containing glutinous rice).

With regard to this little-known product, the only reference at our disposal is a description by Le Poulain (1938). Paak or mam-chao is a condiment, derived from pra-hoc, but is much less common.

For this preparation fish and glutinous rice (*Oryza sativa* var. *glutinosa* Lour.) are used. The principal fish are:

Trey-pruol = *Cirrhinus micropeltis* Sauv. (Cyprinid) or (= *Labeo pruol* Tirant)

Khland-hay = *Macrones sp.* div. (Silurids).

The Trey-pruol is beheaded and eviscerated, without being scaled. If too large, it is cut longitudinally, retaining the vertebral column. The larger Khlang-hay is cut transversely in three parts.

After washing and the usual compression the fish are salted. This is done by hand, as with pra-hoc, the proportion of salt to fish being 2 kgs. of salt to 10 kgs. of fish, or at times only 1 kg. of salt is used to 30 kgs. of fish. No accurate measure can be given as this is entirely dependent on personal taste. After salting, the fish are placed immediately in a jar, which is filled completely. The jar is covered with leaves of the fan palm and crossed bamboo sticks. The fish are left in the jar for 20 to 30 days.

The rice is prepared in various ways:

One method is to use white glutinous rice, prepared by cooking in water for about one hour, two volumes of water being added to one volume of rice, as in the preparation of Chinese soup praba). In order to give a red colour to the rice it is mixed with pounded ang-khak, that is rice which has been fermented by a red yeast-like organism (*Monascus purpureus* Went); this product is imported from China (Went, F.A.F.C.,—1895—*Monascus purpureus*, le champignon de l'ang-quac, une nouvelle Thélébolée.—Annales des Sciences Naturelles. Paris. 7me Série, Botanique, Tome 1, p. 1-18—pl. 1-2). The proportion used is 300 g. of ang-khak to 10 kgs. of white glutinous rice. Moreover 2% of palmsugar is added. After cooking the mixture is spread out on matting to cool. Then the mixture is sprinkled with tinh or with dan-be, the former being roasted rice, the latter a kind of yeast powder. The mass is left to ferment for one night. Thus prepared the rice is ready to be mixed with the fish as will be described.

In a special method the wealthy class use the black variety of glutinous rice, called tra-neup-prahom. Sometimes this black glutinous rice is mixed with white glutinous rice, called tra-neup-sar. The rice is prepared by steaming in the following manner: A container of baked clay, about three quarters full of water, is placed on a hearth. On this container is placed a second earthenware pot, provided with a perforated bottom. A grill, covered with a banana leaf, is fixed at one third of the height of the uppermost container. The black glutinous rice is placed on this grill to be steamed. The steam, rising out of the lower container enters the upper container and the rice is steamed for about one or two hours. When the rice is cooked the mash is spread out on matting as before in order to cool, and is then sprinkled with dan-be, in order to have it fermented. The proportion in which dan-be must be applied is about 1: 100.

The fermented rice or chao is mixed with the fish, previously prepared, and the mixture is placed in a jar. To this end, about 30 to 40 morsels of

fish at a time, are put into an earthen cup, the rice is poured over them, and the whole mass is well kneaded and then packed in the jar. The mam is covered with leaves of the fan palm and small pieces of bamboo matting, which is sprinkled with slightly salted water (about one litre). The water, which prevents contact with the air, penetrates slowly into the mixture. When it has been absorbed or evaporated, more water is added. About one litre of water is needed every 20 days for a jar containing 1 picul (= 60 kg.). The preparation of paâk usually takes about three months. The jar is closed by means of matting, leaves of the fan palm or banana leaves.

Paâk may be consumed after one month of fermentation and it is not absolutely necessary to await the prescribed period of three months.

Mam-ca-sat (*Cambodian fish paste containing roasted rice*).

This mam is a kind of pra-hoc which is manufactured in Cambodia with a small kind of fish called Ca-sat or Trey-chveat (*Pangasius sp.*—Silurid) Le Poulain, 1939, priv. comm.). The fish are headed, gutted and washed thoroughly for half an hour. They are cut into pieces, which are salted in proportion of 1 kg. salt to 7 kg. fish. The whole mass is mixed well and put in a jar. As in the manufacture of pra-hoc, the mass is pressed under bamboo mat with stones on top, and remains for six to ten days in a jar. After that time the fish is transformed to a paste, which is then mixed with roasted and pounded rice. The paste is returned to the jar and is ready for consumption in ten days. The mam is offered to the public in the form of round lumps, which are for sale in every Cambodian market.

This mam may be kept for several years if the jars are hermetically sealed. In order to give an agreeable flavour, certain Cambodians add to the preparation green papaya fruit (*Carica papaya* L) or pineapple (*Ananas comosus* (L.) Merr.) and pounded ginger (*Zingiber officinale* Rosc.)

Mam-ca-loc (*Cambodian fish paste prepared with sugar and roasted rice*).

This mam is manufactured from fillets of Ca-loc (*Ophiocephalus striatus* Bl.) (Chevey & Le Poulain, 1940).

After the fish are beheaded, scaled and eviscerated, the bones are cut out. The fillets, thus obtained are salted on both sides, transferred into a jar, and allowed to stand under pressure for 10 to 30 days; after this lapse of time the salted lumps are taken out and chopped together with ginger (*Zingiber officinale* Rosc.), sugar, pineapple (*Ananas* comosus (L.) Merr.), roasted rice and mak-hak. The latter is a Chinese product, commonly known as "China stick ink", and is added in order to give the mam a distinct colour. The whole mass is then replaced in the jar.

After 5 days, the mam is ready for use. It may be preserved for two months or longer. Care should be taken to keep out the maggots.

The season of manufacture lasts from the end of February till the end of March.

Mam-ruot (*Cambodian paste made with fish entrails*).

Mam-ruot is a product of rural manufacture and local consumption, especially on the great lakes of Cambodia where the people are very poor (Breymann, 1902; Le Poulain, 1939, priv. comm.). This mam is principally manufactured from the entrails and the flesh of the following fish:

Ca-bong	(*Ophiocephalus* micropeltes	C.V.)
Ca-loc	(*Ophiocephalus striatus* Bl.) Ophiocephalids	
Ca-su	(*Pseudosciaena sp.*)	Sciaenid

The entrails are washed, and mixed with the flesh cut in strips. The operation which follows is the same as that for mam-ca-sat.

When the heads of the fish are used instead of the entrails, the product is called mam-dau (Breymann, 1902).

Mam-seing, (*Cambodian paste of fish eggs*).

This mam is prepared from the eggs of certain fish of the lakes of Cambodia, during the months of April or May. The eggs of Ca-bong and Ca-loc are especially used for this preparation.

60 kgs. of the eggs are mixed with 10 kgs. of salt. After this mass has been partly dried, it is mixed with 4 kgs. of roasted rice. It is then preserved in jars for two months before it is ready for consumption and may be kept as long as 5 to 6 months.

Padec, (*fish paste with rice husks from Laos*).

The padec from Laos is somewhat similar to the pra-hoc from Cambodia, differing only in some small details of preparation.

For the preparation of padec, the fish are headed and gutted, sliced, and piled for three days in hanging baskets under the pressure of stones without any salt being added. During this time a stinking juice trickles from the container. Next the mass is removed, pounded with salt, and placed in another hanging basket, made from twisted leaves of fan-palms. In this basket the whole mass is again kept under pressure and the pickle is allowed to drain for another two or three days. After this the

paste is again pounded with more salt and a small amount of rice husks is added. Finally the paste is transferred into jars, in which it is allowed to season.

No data are available on the proportions used, but the analysis of several samples revealed a salt content of about 1%, and moisture content of 50 to 60%.

The Laotians utilize the padec just as the Cambodians do the pra-hoc to flavour the rice or the soup, but if it is necessary it may be the principal food together with rice.

Mam-tom (shrimp paste from Annam and Cochinchina).

This paste is made, from shrimps, along the coast of Annam and Cochinchina (Rose & Brémond, 1918; Brémond, 1919; Brémond & Rosê, 1919). The following species are mentioned as material for this mam (Gruvel, 1925, p. 104):

Con-tom-chieh (*Spirontocaris gibberosa* M.Edw.)
Con-tom-cang (*Alphaeus macrochirus* Richters)
Con-tom (*Penaeus semisulcatus* de Haan (= *P. monodon* (Fabr.)
Alcock), probably identical with Bang-kang.

Besides Bang-kang, Bremond (1919) mentions three other names, Bang-kang-proun, Praht and Kompus, some of which are perhaps identical with the above mentioned species.

The mam-tom is prepared in several ways depending upon the region. The liquid is never utilized as such, since shrimps give only a small quantity of pickle. One form of preparation is reported by Bremond and Rose (see also Gruvel, 1925, p. 247).

A quantity of 12 kg. of shrimps is mixed by hand with 1 kg. of salt, and then placed in a large jar or in a tub. After 24 hours, the shrimps are removed and pressed to squeeze out the pickle, which is kept for later use. The shrimps are half dried and then rubbed to a paste, made as fine as possible, for the quality of the product is based on the fineness of the paste. This paste is returned to the jar or small tub utilized in the beginning, and the pickle is poured over the doughy mass which is stirred with a stick. Sometimes the pickle is boiled before adding it to the paste. The mixture is then exposed to the sun for two weeks or longer. The whole process requires a month and the mam thus prepared keeps for an almost unlimited time. Its quality even seems to improve with age. The product is stored in containers and according to the demand is molded into balls for sale (Breymann, 1902).

Mam-tom of four months is sold at a rate of 5 piasters per petroleum tin, containing 15 litres. (1918).

Mam-ruoc (shrimp paste from Cambodia).

The mam-ruoc on the other hand is made from fresh water shrimps instead of the sea shrimps utilized for the manufacture of Cambodian mam-tom (Pétillot, 1911; Le Poulain, 1939, priv. comm.). The data available do not permit us to judge whether the preparation involves any other essential difference from the mam-tom manufacture.

I wish to call attention here to the two words ruot and ruoc; the former refers to the entrails of fish, the latter designates shrimp.

Preparations, very similar to Cambodian and Laotian pastes are reported from Siam. Pla-chao and kung-chao are made from several kinds of fresh water fish and from shrimps respectively, with the addition of kao-mak, a preparation of glutinous rice. In the case of pla-chao, the fish (= pla) are dressed, washed, salted and stored in jars for 3 days. After that, the pieces are washed and partially dried, and are then, very much as for the Cambodian mam-chao, mixed with the glutinous rice, but also with a small quantity of potassium nitrate. The mixture is put back into the jars and left to ferment for 1 month.

If shrimps (= kung) are used, (either marine or from fresh water) they are headed, washed and salted in a proportion of 1 part of salt to 3 parts of shrimp. After 3 days kao-mak is added, but in case no kao-mak is available, a mixture of roasted rice and sesame is used as a substitute. After being returned to the jar, and being left to ferment for 8—10 days, the kung-chao is ready for consumption, and can be kept about 2—3 months without putrefaction.

Pla-chom and kung-chom are mentioned as Siamese fish or shrimp products prepared with cooked rice. After the usual preliminary treatment, the fish or small shrimps are salted and kept under pressure in jars. The mixing with cooked rice is carried out after several days. Then the mixture is transferred back to the jars and again left to season for some days under a tight cover, after which the preparation is finished with the addition of powdered roasted rice. In a few days, the pla-chom and the kung-chom can be eaten raw with vegetables.

Pla-mam is a fish paste, usually prepared by Catholic Siamese. Fresh *Ophiocephalus striatus* Bl. and *O. micropeltes* C.V. are used exclusively. The fish are first headed, scaled, gutted, filleted and then sliced into pieces. Only flesh and stomach are used; these are mixed together with fine salt and roasted powdered rice. The mixture is then tightly pressed in jars, and left for 3—6 months. After that it is taken out and mixed with some honey or sliced pine-apple and replaced in the jar for seasoning. Pla-mam is either eaten raw with vegetables, or steamed with cocoanut milk and some additional ingredients.

Another important area of production of paste fishery products outside Indochina is Malaya, with the opposite Sumatra coast and the neighbouring smaller islands. Enormous quantities of belachan (small Mysid shrimps) are repeatedly dried, salted and pounded into a paste,

which is also called belachan. Though the real belachan is made only of the small Mysid shrimps, very often stale and rotten fish are also worked up in the large scale production of these pastes. The ready product is packed in cylindrical packages of matting (made from palm or pandan leaves). The largest manufacturing and exporting places for belachan are Bagan Si Api Api in Siak (Sumatra), and Bagan Luar, opposite Penang (Malaya). In this Chinese and Malay mass production, the profit mainly depends on quantity, and hence control of quality is often neglected. A high quality Mysid shrimp paste is, however, produced on the north coast of Java. In Javanese, this product is designated as terasi.

C. Pickles.

Nuoc-man. (*fish pickle from Annam and Cochin-*china).

The manufacture of nuoc-mam has been described in detail and adequately investigated (Legrand de la Liraye, 1869; Tirant, 1885, c.f. Chevey, 1929, p. 106; Baurac, 1898; Rosé, 1918, a,b,c, 1919, a; Mesnard & Rose, 1920; Gruvel, 1925; Guillerm, 1928). The most detailed and original information on the nuoc-mam industry and its chemical aspects is found in Rose's classical publications (chiefly *Bull. Econ. de l'Indochine* but also *Ann. Inst. Pasteur*, Paris).

Nuoc-mam is a fish pickle obtained by salting small fish, usually Clupeids not over 20 cm. long. Literally the name nuoc-mam means "saltish fish water".

The production of nuoc-mam is an active industry, the most important centres of manufacture being situated in the province of Binh-Tuan (South Annam) and on the island of Phu-Quoc. Other centres of production exist all along the coast and it is not an exaggeration to say that wherever the people fish, nuoc-mam is manufactured in more or less large quantities.

In the primitive manufacture (Baurac, 1898) small fish are first kneaded and pressed by hand and then placed with salt in earthenware pots which are tightly sealed. These are then buried in the ground and left there several months. Finally they are dug up, opened and the pickle that has formed is carefully decanted. This is the nuoc-mam.

The procedure of large scale manufacture, as practiced at Mui-Ne in South Annam, is described by Rose. In this industry the following fish are used as raw material:

Ca-com—	*Stolephorus spp.*	Clupeids.
	Clupeoides lile Blkr.	
Ca-lep—	*Engraulis mystax* (Bl. Schn.)	
Ca-moi—	*Dorosoma nasu* (Bloch.)	
Ca-nuc—	*Decapterus spp.*	Carangids.
Ca-tap—	*mixture of various species*	

The fishing season is during the south monsoon from the end of April to the end of September, September being the most productive month.

The manufacture of nuoc-mam requires for equipment only one or more series of vats; five vats constitute the minimum number in a series. The vats, which are of cylindrical shape, are made of the native wood bang-lang (*Lagerstroemia sp.*) and chui-lieu (*Terminalia sp.*), encircled with braided or twisted bamboo. Their dimensions are the following: diameter 1.25 m. to 1.70 m. and height 1.40 m. to 1.50 m.

These vats are provided at the base with one or two taps, simple tubes of bamboo closed with a wooden spigot covered at the end with a piece of cloth. At the inner side of the opening the tap is buried beneath shells sometimes mixed with rice husks. This heap of shells is piled against the wall covering the tap to a height of about 40 cm. The inner opening of the tap is filled with a tuft of hair in order to improve the filtering power of the apparatus, and the liquid escapes only in a small stream.

The relative quantity of salt to fish varies with the species of fish used, and also with the different strata of the vat. To some species of fish proportionally more salt is added to the upper stratum than to the middle or the bottom. The relative number of baskets of fish and salt are the following.

fish		salt		
		bottom	middle	top
Ca-com, Ca-lep or Ca-nuc	6 baskets	3	4	5
Ca-moi or Ca-tap		5	5	5

A small quantity of salt is added to each measure of fish and stirred to bring about uniform salting. After the vat is filled to the brim, a mixture of salt and fish is placed on top of the vat to form a conical heap, and more salt is added to cover the whole mass completely.

After the salted fish have stood for three days, the initial pickle, the so-called nuoc-boi, is drained off slowly during about three days.

According to Guillerm (1930, p. 128) the turbid and reddish brown pickle loses its colour easily and becomes clear on contact with the air.

Meanwhile the fish have settled below the top of the vat, and the pile of salt has almost disappeared. The fish are now tramped thoroughly so that the upper surface is smooth. Finally the fish must be placed under pressure. In order to do this, the surface is covered with a layer of cocoanut leaves and two semicircular bamboo trays with the parallel

sides touching. Then some slats are placed on top, and pressure is obtained by forcing wedges between the slats and two bars fixed transversally to form a clamp.

Next the nuoc-boi at first kept aside is poured over the fish in order to maintain a layer of liquid of about 10 cm. over the fish. This is said to prevent the fish from becoming contaminated with fly larvae. The fish are left standing to macerate; the length of time depends upon the species of fish used:

Ca-nuc = 4½ months; Ca-com and Ca-lep = 3½ months; Ca-moi and Ca-tap = 1 year.

After this lapse of time, the pickle is permitted to run off at a rate of 40 to 60 jars (of 7 litres each) per 24 hours. The first pickle to be drawn off is nuoc-mam of first quality or nuoc-nut. The quantity of nuoc-nut recovered from each vat may be as much as 60 to 80 jars.

The vats emptied of the first harvest of nuoc-mam are then leached in order to increase the yield with a second quality product. In order to obtain this increased yield, fresh brine is poured over the fish in the first vat of a series; the second quality nuoc-mam so obtained is then tapped, again at a rate of 40 to 60 jars a day. As soon as the quality becomes inferior, the extract from the first vat is used to leach the second vat and so on, leaching each vat of a series with a fluid which has already passed through the foregoing vats in succession. In this way, 500 to 800 jars of liquid are passed through each of the vats.

Before leaching, the covering layer of leaves is removed, and the exposed fish must be again covered with salt. Sometimes a hole is made in the centre of the residual mass, and caramel is added. This ingredient darkens the colour and imparts a certain flavour to the product. At the same time this procedure is said to improve the keeping properties of nuoc-mam of the poorer quality (Rosé, 1918, a,c; Guillerm, 1928). About 30 years ago, german dyes (fucsin) were imported and used to darken the product but they did not improve the keeping properties (Rosé, 1918 a, p. 159).

At Mui-Ne, Ca-moi and Ca-tap are ordinarily used for the preparation of a pickle which is taken after 3 to 5 months to leach the vats with the other species. This procedure adds to the production and yields a greater quantity.

The undissolved fish residuum, the so called xat-mam or nuoc-xat is obtained as a byproduct, and is usually sold as fertilizer.

When using the fish, Ca-moi (*Dorosoma nasus* Bloch.) as the raw material, an oil is also obtained which floats to the surface during seasoning (Marcelet, 1929). In the following pages this product will be discussed in more detail.

The second centre of production is the island of Phu-Quoc, in the Gulf of Siam near the coasts of Cochinchina and Cambodia. Here the manufacture is not uniform, and several methods are used differing only in slight detail. One of these methods is fully given by Rosé (1918 a).

In this procedure several kinds of Ca-com are used, e.g.

Ca-soc-trang *Stolephorus heterolobus* Rüpp.
Ca-soc-phan *Stolephorus indicus* v. Hass.
Ca-soc-tieu *Stolephorus tri* (Blkr.)
Ca-com-do *Stolephorus zollingeri* (Blkr.)

The season lasts from the end of August till the middle of February, with the highest production in October and November. The fisheries are especially fruitful during the period of the monsoon change.

A number of vats made of the wood boi-loi [2], joined with bark of the tree tram (*Melaleuca leucadendra* L.—M. *cajuputi* Roxb.) constitute the major part of the equipment for manufacture. These vats rather vary in size and in form, but as a rule the vat content is about 20 to 30 piculs of fish and 12 piculs of salt. The ratio of salting thus ranges from 1:3 to 1:2.

Immediately after the catch, the fish and the salt are mixed by hand, thrown into the vat, piled high above the top and the whole is then covered salt.

After 3 days, the initial pickle or nuoc-boi is tapped and kept separate. The heap of fish is levelled and pressed below the top of the vat, covered with leaves of the nipa palm (*Nipa fruticans* Thunb.), and with a tray covering the whole. The contents of the vat are then kept under heavy pressure by crossed slats held in position by clamps. The nuoc-boi is then poured over the fish.

Ten days later (that is on the 13th day from the beginning) the pickle is again tapped. The first half of it has a bad odour and is poured back over the fish, the second half of the pickle is the nuoc-mam of first quality.

[2] It is not quite clear whether the author means *Tritaxis gaudi-chaudii* Baillon (Euphorbiacee) or *Litsea vang* Lecomte (Lauuracee). The Annamite names of these two species differ but in some accents, not indicated by Rose.

After 10 more days (that is, on the 23rd day from the beginning) all the pickle is drained off. The greater part of this harvest is of second quality, only the last fifth being of first quality.

Then a small portion of the residual fish is transferred to a small container, and stirred with a boiling brine (60 kg. of salt and 280 l. water). The liquid thus prepared is poured over the contents of the large vat. After 10 days or on the 33rd day from the beginning, the new pickle is tapped, and poured back over the fish. This is repeated after 10 days. At last, on the 63rd day, the pickle is drained, the first 70% being of 3rd quality and the last 30% 2nd quality.

The leaching is repeated three times, the last extraction requiring three months and a 3rd quality nuoc-mam results.

Though at Phu-Quoc several different procedures are employed, they all agree in one respect, namely that the harvest starts much earlier than at Mui-Ne. This is perhaps not due to the difference in methods, but may be ascribed to the more delicate fish at Phu-Quoc, in which digestion takes place easily.

From North Annam considerable variation in methods has been reported by Rosé (1918 c). It would be confusing to cite all these details, and therefore we shall confine our attention to some cases that are of special interest.

At Ly-Nhon rather large fish (30 cm.) are salted in the round, one picul of salt being used for two piculs of fish. Some days later the nuoc-boi is tapped and poured back over the fish. Four months later, a certain quantity of brine and caramelised honey is added in order to obtain the 1st quantity nuoc-mam. After leaching, the residual fish is cooked in brine, which is then used for the leaching of other containers involved in the production.

At Dong-Hoi the fish is salted in proportion of 1 basket of salt to 3 baskets of fish. After 15 days the nuoc-boi is tapped. Then roasted and pounded maize is mixed with the fish, the nuoc-boi is cooked and poured over the fish when boiling.

At Guong-Giang the nuoc-boi is usually tapped and boiled on the 3rd or 4th day, while roasted rice is added to the fish instead of maize. The addition of roasted rice is also reported from many other places in North Annam, especially when the fish is slightly salted, e.g. at a proportion of 1 to 10 in weight.

As a general feature of nuoc-mam preparation in North Annam, we may note economy in use of salt and excessive leaching of the fish. In many cases the boiling of the nuoc-boi, and the addition of tinh keeps the poor product from putrefying. Because of the inferior quality produced, Rosé has mentioned the practice without appreciation, but nevertheless these native preservation techniques are very remarkable and deserve scientific research.

In North Annam the residual fish mass is sometimes worked up into mam, after the first nuoc-mam is tapped. This is practised according to the demand for mam and for nuoc-mam.

A special variation of nuoc-mam preparation is reported from the province of Cantho in the extreme West of Cochinchina (Chevey, 1931, p. 29). Here the fish are first gutted and then salted as in the pra-hoc preparation. Pineapple juice is added afterwards to effect the digestion of the flesh.

In Tonkin nuoc-mam is prepared from fresh water fish. The procedure differs only in one respect from the ordinary manufacture, the fish being gutted before salting.

In the South the nuoc-mam is marketed in earthen pots containing 3 to 3½ litres; in the North (Tonkin and North Annam) it is marketed in large tins or in large, internally glazed earthen pots of over 100 litres. All these containers, when filled with nuoc-mam, must bear a label with legend "nuoc-mam of the South" or "nuoc-mam of the North" and an indication that the contents conform to regulations. This legend must be given in three languages: French, Chinese and Quo-ngu (Cordemoy, 1932).

The market price of nuoc-mam varies from 0.03 to 0.40 piasters per litre, averaging from 0.10 to 0.20 piasters (Rosé, 1918 a & c).

The nuoc-mam production of Indochina is consumed almost completely by the inland trade, although formerly exports were made to Siam and Malaya. It is not easy to determine the total annual production so that the estimates range from 35,000 to 100,000 tons of nuoc-mam per annum (Gruvel, 1925, p. 246; Cordemoy, 1932). The economic part played by the nuoc-mam is some regions may be estimated from the amount of salt used. In the year 1925 the total salt used in the province of Binh-Tuan aggregated 15, 130,800 kgs., 15,000,000 kgs. of which were intended for the manufacture of 40,618,160 litres of nuoc-mam (Guillerm, 1928, p. 36).

The most important markets for this product in the South are those of Saigon and Cochinchina, which consume the well known products of Binh-Tuan and of the island of Phu-Quoc. For the North (North Annam and Tonkin) the markets of Nam-Dinh and of Hanoi may be mentioned, which are,

however, far less important than those of the South (Cordemoy, 1932).

During the world war of 1914-18, the shipping of nuoc-mam became urgent for the supply of Annamite troops in Europe. The earthern pots of 5 to 6 litres proved to be rather unsatisfactory. In order to meet the difficulty, the volume of the nuoc-mam was reduced by evaporation and the heavy syrup thus obtained, could be easily packed in tins Rosé, 1919 d). The evaporation was carried out in pots placed in hot sand over a fire, and a continuous stirring prevented the boiling mass from scorching. For use 1 kg. of the condensed product was diluted with 3½ litres of water, yielding 4 litres of nuoc-mam. 50 cc. of the diluted product make a man's ration.

Nuoc-mam is said to be submitted to continued evaporation and sold dry. This is practised only occasionally in the Northern provinces Merle, 1880).

Ca-mam (a fish pickle reported from Tonkin and Siam).

Ca-mam is a fish pickle of far less importance than nuoc-mam, made in Tonkin and Siam of fresh water fish, and concerning which there is only scanty reference in literature (Chevey & Lemasson, 1937, p. 182).

The preparation is described as follows: the fish are gutted and mixed with salt in the proportion of 1 part of salt to 2 parts of fish; sometimes some alcohol and chopped leaves of the betel (*Piper betle* L.) are added, and the whole mixture put into a jar, which is carefully closed. The ca-mam thus obtained can be consumed after two months.

Tuk-trey (boiled fish pickle from Cambodia).

Tuk-trey is a liquid condiment obtained as a byproduct in the manufacture of salted and dried fish on the lakes of Cambodia (Chevey & Le Poulain, 1940).

The pickle from the brine tanks is boiled and then strained through an old salt sack. This filtering is repeated twice, a finer cloth being used the last time. After this, the pickle is boiled again for 5 minutes and then transferred into jars which are tightly sealed. The tuk-trey may be preserved for one year. This product replaces the nuoc-mam in the diet of the coolies on the lakes, but the nitrogen content of the substitute is much inferior to that of the real nuoc-mam.

Nuoc-mam-gau-ca (fish liver pickle from Cambodia).

This product is prepared from the livers of Ca-tra (*Clarias sp.*) and of Ga-bong (*Ophiocephalus micropeltes* C.V.) (Chevey & Le Poulain, 1940).

10 kg. of unwashed livers are salted with 1 kg. of salt. This mixture is placed in jars, which are exposed to the sun for eight to ten days for active fermentation. After this lapse of time, 10 litres of pickle and half digested livers are poured in a shallow iron pan, together with 7 litres of water and 150 gr. sugar. Then the liquid is boiled for one hour, in order to dissolve the livers. The product thus obtained is strained through a cloth and finally filtered through Chinese paper.

The nuoc-mam-gau-ca is now ready for immediate use, or it may be stored in tightly sealed jars and preserved for many years.

Nuoc-mam-ruoc (shrimp pickle from the Gulf of Siam).

When shrimps are treated in the same way as fish, and some brine is added, a product analogous to nuoc-mam, but of quite a different flavour is obtained. This is the so called nuoc-mam-ruoc, which gets its name from the fact that it is prepared from ruoc, a type of shrimp found along the islands of the Gulf of Siam (Tirant, 1885, cf. Chevey, 1929, p. 47).

The use of tinh (roasted rice or maize) and other additional ingredients.

The preparation of several mams includes the addition of tinh (that is, roasted and pounded rice or maize, screened or unscreened). The action of adding the roasted matter is also called tinh. After the addition of tinh, the salted fish remains firmly pressed in the jars, and afterwards is usually exposed to the sun. This is a preservation technique, that is applied also to the large scale production, and deserves special attention because of its advantages (Chevey, 1938, priv. comm.).

1. The tinh is said to retard the rate of disintegration a certain extent, thus improving the keeping property of the mam.

2. The tinh gives a special odour which is desired and demanded on the market. The odour depends on the type of tinh used. The roasted and pounded rice is much used in Cochinchina and even more in Cambodia. The maize is used particularly in Annam and also in Tonkin.

3. The tinh gives to the mam a reddish colour, more desirable for commercial use than the greenish colour of the fish that is preserved with salt only. The reddish colour is not obtained with the tinh without the combined action of the sun, which makes

the manufacture of mam with the addition of tinh possible only in the dry season.

4. The tinh is said to counteract the salt taste of the products under the action of the sun.

The use of tinh is also reported in the preparation of salted and dried fish in Tonkin (Chevey & Lemasson, 1937, p. 182) and in the manufacture of nuoc-mam in North Annam (Rose, 1918 c). This practice is not confined to Indochina, but is known also in Siam and South Borneo.

Tinh and rice bran are likely to contain antioxidants, and these perhaps aid in improving the keeping property of the products. On the other hand, the caramelised compounds in the roasted ingredients perhaps exert some bactericidal activity.

The preserving action which is attributed to cooked rice and such like fermenting ingredients suggests the formation of organic acids (e.g. lactic acid) or other compounds, checking protein putrefaction.

In conclusion, we may state that our understanding of these old empirical preservation techniques is, to say the least, still very incomplete. The subject is highly complex, involving a variety of chemical and biochemical aspects.

D. Fish oil.

Preparation methods.

Most of the fatty matter, extracted from fish, is completely liquid at 30°C, which is a normal temperature for the country, so that it may be considered fish oil. The trade, however, makes a distinction between "huile" (=oil), and "graisse" (=grease), the former being prepared from sea fish, the latter from fresh water fish.

Native oil reduction on a large scale is practised with fresh water fish of Cambodia (Finelle, 1923; Chevey & Le Poulain, 1939, 1940), and with sea fish on the coast of Annam in the province of Phan-Tiêt (Marcelet, 1929).

In the primitive manufacture of fish oil, the Cambodians extract a certain quantity of oil by rudimentary means, chiefly from the entrails. The raw material is exposed to the sun on trays, the oil separates and trickles down into the pots below, containing a little water. When the pots are full, they are allowed to stand in the sun for several days, and the oil gradually floats to the surface of the putrid liquid. The oil is skimmed off with a large wooden spoon and transferred to petroleum tins in which the stinking oil is usually stored.

In addition to this primitive procedure, Cambodians prepare oil by cooking small fish (Cyprinids) or the entrails of the fish used for drying. The raw material is cooked with fresh water in iron pots, and after several hours the floating oil is gathered with a wooden spoon, then roughly decanted and stored in petroleum tins. Since the entrails used for the procedure are already putrid before being cooked, the oil has an offensive odour.

On the coast of Annam near Phan-Ri and Phan-Tiêt, the oil is extensively obtained only from Ca-moi (*Dorosoma nasus* Bloch.) (Clupied) during the months of February, March, April and May, and again in November and December. The last season is especially favourable for oil making, since the Ca-moi are exceedingly fat at this time. The oil is obtained by cooking the fish with brine in petroleum tins. Layers of fish and layers of salt are alternately placed in the tins and a 10% brine is poured over it. After 5 hours cooking the liquid is poured off, allowed to cool and the oil is then decanted. One petroleum tin, containing 20 kg. Ca-moi, will give one litre of oil.

The cooked Ca-moi remains in the tins that have been used for the operation; after having been thoroughly drained, the containers with the fish are sent to Cochinchina, where it is highly esteemed as food.

Ca-moi oil also obtained as a byproduct in the manufacture of nuoc-mam, as we have already noted in the preceding pages. In this process salt is used in a proportion of three baskets of Ca-moi to one basket of salt. This mixture is allowed to season in large vats of 3 tons capacity. As has been described previously, the pickle is drained for three days. Then the tap is closed, and the contents pressed by a bamboo tray with stones on top, and the pickle that has been kept aside is again poured over it. The seasoning for the nuoc-mam manufacture takes several months, but within a few days the oil will float on the surface, where it is gathered as soon as it appears. One vat of 3 tons capacity, in which the quantity of salt amounts to 1250 kg. and the fresh Ca-moi to 1800 kg., will yield 170 litres of oil with the fat Ca-moi of October-November, and 100 litres with the medium fat Ca-moi of March-June.

The commercial quality of oil depends on the amount of foreign material that remains in suspension, and also on the quantity of water in the bottom of the tins. The decantation of the oil is usually carried out rather carelessly so that considerable quantities of water and of flaky detritus that will not separate easily, are poured off with the oil, giving it a turbid appearance.

The foreign material is estimated at sight by the buyers. The water content is estimated by dipping a stick, with dry rags attached, to the bottom of the container; the rags will absorb oil, and water if

present. If the rags contain water, they will not burn, or only with much crackling; if they contain oil they will burn without noise.

Contamination is practised by emulsifying water in the oil (Finelle, 1923.). When heated, a contaminated sample will deposit a pasty substance, which will not liquefy, since it contains starch and cellulose debris originating from the broken rice or the rice husks used for emulsifying the water.

In native life, the fish oil is principally used in lamps. Possibilities of modern industrial application have been investigated by Marcelet, 1928, b, 1929), and will be discussed in our third section.

Foreign commerce in fish oil is of notable importance. About 1500 tons of oil are exported annually from Cambodia to other countries in the Far East, and Northern Europe. One picul of 62 kg. costs 8 piasters (Chevey & Le Poulain, 1938, 1940).

SECTION II. CHEMICAL RESEARCH

A. Nuoc-mam and allied products.

Preliminary tests.

The inferior quality nuoc-mam is often produced by excessive lixiviation. The manufacturer is able to judge the quality of the nuoc-mam by the quantity obtained. For the buyers, however, it is not such an easy matter, but it is said that one can roughly estimate the quality by the persistance of the odour on a finger dipped in to it. The odour of excessively leached nuoc-mam is washed off easily, but that of first quality nuoc-mam persists.

The practice of excessive leaching has led to an inquiry into the customary methods of manufacture, and a chemical investigation was made at the same time. The methods of analysis have been described in detail (Rosé, 1918 a; Guillerm, 1928), partly in connection with maintaining legal standards.

The chemical investigations started with a series of qualitative tests:

Millon's test. When diluted nuoc-mam is heated with acetic acid, a slight turbidity indicates traces of albumines.

After heating and filtering the nuoc-mam in order to free it of albumines, neither a) picric acid b) Brücke's reagent nor c) a 10% solution trichloracetic acid gives any precipitate, indicating that no proteoses are present.

A positive biuret reaction reveals traces of peptone.

Tryptophane is easily detected by the violet colour and by the precipitate, given by bromine water.

Quantitative analysis.

Subsequently quantitative analysis was made by the following methods:

Dilution of samples: For analytical purpose nuoc-mam samples are diluted twentyfold.

Acidity: 50 cc. of diluted nuoc-mam are transferred into an Erlenmeyer-flask; 4 drops of a 3% alcoholic phenolphthalein solution added and titration carried out with 0.1 N NaOH.

Total nitrogen (after Kjeldahl): 10 cc. of diluted nuoc-mam, 15 cc. of sulfuric acid and 1 drop of mercury, are transferred into a Kjeldahl-flask of 700 to 800 cc. Complete digestion is accomplished by heating in the usual way. Next about 250 cc. of distilled water and about 2 g. of sodium hypophosphite are added and the mixture slightly heated until all the mercury has been turned into a gray precipitate. Excess sodium hydroxide solution is added and about 2/3 of the total volume distilled in a suitable apparatus (after the method of d'Aubin or Delattre) and collected in a receiver of 250 cc. of 0.1 N H_2SO_4 and 2 cc. of cochineal tincture. Titration is carried out with sodium hydroxide solution until the cochineal turns violet.

Volatile bases: 50 cc. of diluted nuoc-mam 100 cc. of distilled water, some magnesia and several pieces of pumice stone, are placed in a distilling flask of 600 to 800 cc. capacity. Distillation and titration are carried out in the same way as in the determination of total nitrogen.

Formol titratable nitrogen (after Sorensen modified by Effront):

(Effront.—Les catalyseurs biochimiques dans la vie et dans l'industrie.—Edition Dunod & Pinat, Paris, 1914).

This determination requires the following reagents: 1). A solution containing 0.5% phenolphthalein in 50% alcohol. 2) Litmus paper of high sensivity. 3) A formaldehyde solution, freshly prepared in the following way: To 50 cc. of commercial formaldehyde, 2 cc. of the phenolphthalein is added, and 0.1 N NaOH, sufficient to turn the colour pink. 4) A saturated solution of baryta, $Ba(OH)_2$ in methyl alcohol. In order to carry out the determination, 50 cc. of diluted nuoc-mam, 1 cc. of solution of phenolphthalein in 50% alcohol, and 2 g. of $BaCl_2$ are transferred into a graduated flask of 100 cc. capacity. The baryta solution is then added drop by drop, sufficient to give the solution a pink colour, and an additional 5 cc. added. The solution is allowed to stand for a quarter of an hour, and then filtered if necessary. The first determination is done with 25 cc. of this filtrate, which is first made neutral to litmus paper with 0.1 N HCl. Then 10 cc. of the formol solution is added, making the liquid acid; it is now titrated with 0.1 N NaOH until the colour turns pink.

A second titration is carried out with another 25 cc. of the filtrate.

Amino acids: The amount of nitrogen of amino acids is calculated by subtracting the nitrogen of volatile bases from the formol titratable nitrogen.

Chlorides. (after Charpentier-Volhard): 10 cc. of diluted nuoc-mam, 30 cc. 0.1 N $AgNO_3$ solution, 5 cc. saturated ferric alum solution, 5 cc. strong pure HNO_3 and 100 cc. of distilled water, are transferred into an Erlen-

meyer flask of 250 cc. capacity. The solution is titrated back with O.1 N KCNS until red.

Nitrogen partition in nuoc-mam and legislation.

As a result of the pioneering research of Rosé it was stipulated in the decree of December 21st, 1916 that the total amount of nitrogen might vary from 15 to 25 g. per litre, and the amount of organic nitrogen from 10 to 20 g. per litre. 50 to 77% of the total of nitrogen must be titratable with formol (amino acids and volatile bases) and no more than one half of this nitrogen may belong to volatile bases (principally ammonia).

This matter was again settled by decree on April 23rd, 1933. Since then the total amount of nitrogen required is:

for nuoc-nut 18 gr. per litre.

for nuoc-mam of the South 15 g. per litre and

for nuoc-mam of the North 5 g. per litre.

According to the decree promulgated by the Governor General (October 13th, 1933) certain tolerances for the nitrogen contents are allowed. A tolerance of 4 g. per litre is allowed for nuoc-nut and for nuoc-mam of the South and a tolerance of 2 g. per litre for nuoc-mam of the North.

A nuoc-mam of 20 g. total nitrogen should contain at least 240 g. NaCl per litre, whereas 200 g. per litre is sufficient for qualities richer in nitrogen (Guillerm, 1928, p. 48). A slight salting of the fish causes putrefaction, in other words a predominance of ammonia nitrogen over the amino acids. Excessive salting on the other hand, reduces the ammonia-amino acid ratio to a minimum, but at the same time retards the digestion of the proteins, thus keeping down the nitrogen content of the nuoc-mam (Rosé, 1918 a).

The proportion of nitrogen of volatile bases (ammonia etc.) to amino acid nitrogen may be roughly judged by the pH, for the reaction should be acid to phenol-red. In order to have inferior and even putrid nuoc-mam meet this requirement, boiling is sometimes resorted to, though this was not the intention of the law.

In chemical composition nuoc-mam greatly resembles the so called soyou, a Japanese sauce, made of soy-beans (*Soya hispida* Sieb. et Zucc.) (Rosé, 1918 b).

Supplementary research on Nuoc-mam.

Later an attempt was made to obtain a more detailed analysis of the partition of the nitrogen in nuoc-mam (Peirier & Nguyen-Kim-Kin, 1933), by using the methods indicated by Sorensen and by Willstätter. Although the results of this investigation are unreliable in detail, polypeptic, purinic, diamino-acid and ammonia nitrogen seem to have been detected.

Some years later the investigation of nuoc-mam was undertaken once more by M. Autret & A. Vialard-Goudou (1939).

The tryptophane known as an indispensable constituent of the human diet, was examined first. After a careful choice among the methods described in literature, the authors adapted the colorimetric method after Voisenet (1905, *Bull. Soc, Chim.* Vol. 33, p. 1198) modified by Furth & Lieben (1920, *Bioch. Zeit.* Vol. 109, p. 124). The reaction is based on a violet coloration caused by tryptophane in the presence of formaldehyde and sodium nitrite, in a strong hydrochloric medium. This reaction appeared not to be disturbed by the presence of NaCl.

The colour readings were carried out with an electric photo-colorimeter, using a red screen. 72 samples have been tested in this way and the tryptophane content turned out to range from 0.21 g. to 1.35 g. per litre. In conformity with the decree of October 13th 1933, the tryptophane content in ordinary samples varies from 0.29 to 0.55 g. with a mean value of 0.37 g.

Contrary to the tryptophane determination, the methods for other amino-acids, as for instance tyrosin and arginin do not hold good in ordinary nuoc-mam (Autret & Vialard-Goudou, 1940). This is due to the considerable quantities of NaCl present in the samples (210-290 g. per litre).

In order to remove the salt, the samples are evaporated under low pressure and the residuum is washed in a mixture of 100 cc. alcohol (94-95%) and 20 cc. strong hydrochloric acid. In this mixture NaCl dissolves but little, so that the salt crystals remain behind. The solution is again evaporated at low pressure and the residuum is finally dissolved in water.

The authors made certain that the nitrogen partition remained unaltered by this treatment. In this work considerable experience was gained in the determination of some amino-acids. Suitable methods for tyrosin, cystin, arginin, histidin and lysin are listed. As yet no numerical data are given on the composition of nuoc-mam.

Then a study was made of the sulphur compounds of nuoc-mam (A. Vialard-Goudou & Dang-Van-Tien, 1941), to examine the occurrence of decay in which H_2S develops. In order to prepare a microbiological investigation the partition of

sulphur in nuoc-mam over its principal forms e.g. total, organic and inorganic compounds was studied.

The determination of the inorganic sulphur compounds was carried out by precipitating them as barium sulphate which only takes place quantitatively under controlled conditions.

To determine the total quantity of S the organic sulphur compounds are first mineralized. The destruction is carried out in a Kjeldahl-flask and is attained by combining an oxidation with nitric acid and copper with an oxidation by perchloric acid. The technique needs to be practised in order to prevent explosions. After this the total quantity of organic sulphur compounds precipitated as barium sulphate can be determined.

The quantity of organic sulphur compounds is computed by subtracting the inorganic sulphur from the total sulphur.

It was found, that the organic sulphur content of nuoc-mam varies from 0.54 to 1.165 g. per litre, the greatest amount usually being found in nuoc-mam containing the greatest amount of organic nitrogen. Furthermore the ratio of organic nitrogen and organic sulphur was computed, and appeared to be rather variable, the extreme values being 8.6 and 15.4; it is therefore not possible to deduce the quantity of organic sulpuhur from the organic nitrogen.

In nuoc-mam the quantity of inorganic S surpasses the quantity of organic S. There is no correlation between the quantity of inorganic S and the quantity of salt.

Shortly before the war some additional work was done by A. G. van Veen (Eykman Inst. Batavia, Java) (priv. comm, 1940). Dialysis experiments have demonstrated that in nuoc-mam the proteins have indeed been digested practically 100%.

On special request of Guillerm, van Veen carried out determinations of vitamin B_1 no trace of which could be detected, and the same was the case with the other B vitamins (B_2—complex).

Enzymes.

Many variations in the methods of nuoc-mam preparation have been reported, but they all come to the same fact, that the meat of the fish is dissolved. The pickle contains in the beginning, therefore, essentially dissolved proteins (biuret reaction). The proteins are slowly decomposed and there are given off principally amino acids (and ammonia).

Since the solution of the proteins and the subsequent decomposition into amino acids takes place even if the entire process is kept sterile by the use of chloroform, it was believed that the action was due to enzymes. The investigation was, therefore, directed towards the enzyme action and began with the study of salt free solutions (Mesnard & Rose, 1920).

A chloroform extract was prepared by hanging bruised fresh fish, wrapped in a cloth, in chloroform vapour under low pressure. The juice from the fish was collected for a period of 24 hours and its action on gelatine investigated. The juice thus prepared from the meat did not liquefy the gelatine, while a chloroform extract of the organs, on the other hand, proved to be highly active upon gelatine but this action did not continue long. For that reason a preparation was sought that would be more persistently active. To this end glycerine extracts were prepared as follows:

The fish was bruised and mixed with an equal weight of glycerine without the addition of salt, and after standing for 48 hours at 30°C, was filtered. This glycerine extract was less active than the chloroform extract, but remained active longer, and was therefore more suitable for further investigation.

The action of these extracts on the following substances was studied:

gelatine (liquefaction).

coagulated eggwhite (clarification and solution).

peptone (disappearance of biuret reaction and increase of amino-acids—formol titration).

In these experiments the salt free extracts were preserved from putrefaction by toluol. The results were as follows.

substance examined	gelatine	coagulated egg white	peptone
fish meat	–	–	+
Glycerine extract of fish organs	+	+	+
Fish pickle	+	–	–

Thus only the juices of the organs are able to decompose the proteins from the beginning, while those prepared from the meat were only active when decomposition had already begun; the latter being able to decompose the intermediate products such as peptone. The fish pickle is not the active agent, since most of the process takes place in the body of the fish. The principal function of the pickle is to hold the decomposition products in solution and to retard the growth of the aerobic bacteria. Thus the juices of the organs prove to be the most important solvent in the preparation of the nuoc-mam and for that reason a further study was made of the glycerine extract of these organs.

The optimum temperature for the action on gelatine proves to lie between 36° and 44°C. Furthermore, it was found that the glycerine extract was active exclusively in a neutral or alkaline medium. A weak acid reaction hinders the digestion of coagulated egg-white very markedly and less amino acids are formed.

Salt also slows up the enzyme action. 20% of salt (NaCl) reduced the activity of the enzyme to one third. A nuoc-mam of good quality contains from 20 to 25% of salt. If a specimen contains less salt the enzymes can react better, but unless some disinfecting medium is used the aerobic bacteria multiply so rapidly that putrefactive action predominates.

Keeping properties.

As we have seen above, Rosé has stated as a criterion of good nuoc-mam that the amount of formoltitratable nitrogen should amount to at least half of the total nitrogen. Should a nuoc-mam contain less amino acids it is unstable because of the ammonia formed, which may occur even when the product is sterile.

This criterion of Rosé appears indeed to be a guarantee of durability. The amino acids themselves act as preservatives, a fact that is clearly shown in the case of the condensed, salt free "nuoc-mam" prepared in the laboratory under sterile conditions, and reduced to one quarter of its original volume (Guillerm, 1928, p. 39). This liquid may be kept for an almost indefinite time, which is ascribed to a high content of amino acids. A low ammonia—amino acid ratio in the solution procures an acid reaction.

The durability of commercial nuoc-mam also coincides with an acid reaction (low pH). Good nuoc-mam diluted with distilled water in the proportion of 1 to 10 or 20, should give a clear yellow colour with phenolred. If there is a tinge of red, it cannot be kept for long without undergoing putrefaction.

As we have seen above, in North Annam tinh is added to the nuoc-mam and sometimes molasses or maize which has first been boiled and then roasted (Rosé, 1918 a & c; Guillerm, 1928). This serves amongst other things to render the colour of the poorer qualities somewhat darker when the leaching has been carried too far; but it also seems to have a certain preservative action, possibly because the carbohydrates of the tinh, maize or molasses are converted to acids by bacterial action. In addition, the use of several roasted ingredients suggests a bactericidal activity of caramelised carbohydrates. At any rate it appears that by these additions it is possible to economize in the use of salt in the case of nuoc-mam that is so unstable and alkaline that even saturation with salt would not stop putrefaction. In some instances it appears possible that a ratio of 1 part of salt by weight to ten parts of fish is sufficient.

In some regions the addition of tinh is supplemented by another process. Three or four days after the first salting the pickle is drained off, boiled and again poured over the fish (Rosé, 1918 c). In the publication describing this method it was regarded as a primitive attempt at sterilisation. This comparatively rough and ready process can, however, have no real significance in that direction and its true purpose is still obscure.

Nitrogen partition in solid condiments.

In connection with the investigations on nuoc-mam, some work has also been done on the solid condiments, pra-hoc, pa-dec and mam-tom.

These pastes have a soluble and an insoluble content. The soluble fraction consists of the digested flesh, and of the mineral salts, nearly all of which originate from the sea. The insoluble fraction consists of the unaltered parts of the flesh and of insoluble salts.

When dissolved in water, the soluble fraction gives a solution, which closely resembles nuoc-mam, even the partition of the nitrogen compounds, but the ammonia nitrogen sometimes predominates over the amino acid nitrogen especially in older samples.

Based on the analysis of a few samples, Brémond and Roseé (1918, 1919) give the following limits for the three condiments:

moisture	52—63%
soluble fraction	26—30%
insoluble fraction	8—17%

In describing the partition of the nitrogen within the soluble fraction, the authors give the following data computed in percent of total soluble nitrogen.

	pra-hoc	pa-doc	mam-tom
organic nitrogen ..	80.0	75.2	68.9
formol titratable nitrogen	52.5	51.6	60.2
amino acid nitrogen ..	32.5	26.8	29.1
volatile nitrogen (ammonia included)	20. —	24.8	31.1

The insoluble nitrogen amounts to only the minor portion of the total nitrogen, as may be seen from the following percentages:

in pra-hoc	47
in pa-dec	35
in mam-tom	10

B. Fish oil

Estimation of quality.

The quality of fish oil depends almost entirely on the water content. In practice this is roughly estimated by burning a rag which has been dipped into the oil, as already described (Finelle, 1923). Attempts have been made to carry out more exact determinations, but considerable difficulty was experienced in taking random samples, since the water quickly accumulates on the bottom of the containers, even after a thorough stirring of the oil. Some inconvenience was also caused by an increase of weight of the samples stored in a stove at 105°C, which was due to oxidation. The water-content of uncontaminated samples ranges from 0 to 2½% . Oil containing more moisture may be regarded as contaminated.

Chemical methods and results.

The investigation of fish oil, especially that made from *Dorosoma nasus* Bloch. was subsequently taken in hand by Marcelet (1928, a, 1929). In respect of the possibilities of technical applications of the oil its physical properties were examined. The chemical investigation was initiated with some preliminary test.

Acidity, indicating the content of free acids in % weight. An oil sample of 100 g. was dissolved in 10 cc. chloroform and 10 cc. neutralised alcohol 95%, containing some phenolpthalein. Titration was carried out in the ordinary way with a standardized NaOH solution. The acidity ranges from 2½ to 12% or still more according to age. This index may be regarded as a measure of preservation; the purer the oil, the better its keeping properties and the lower its acidity. The dark-coloured oil, obtained as a by-product in the nuoc-mam manufacture, contains much more free acid than the cooked samples.

Iodine index (after Vijs). This index indicates the amount of iodine % of weight that can be fixed to the fatty substances. The determination is taken as a measure of the amount of unsaturated constituents. The results were similar to those obtained with other fish oils.

Saponification index, indicating the amount of KOH that can be bound to free or esterified fatty acids. The tested samples appeared to contain only small amounts of unsaponifiable matter, ranging from 2 to 3%, which is similar to the constitution of other fish oils.

Fatty acids. With the technique of the lead salts, the unsaturated fatty acids were separated from the saturated. The saturated acids were separated into several fractions by means of repeated crystallisation after being dissolved in hot alcohol.

In this investigation it was found, that the oil from *Dorosoma nasus* may contain considerable amounts of unsaturated fatty acids. The bulk of the saturated material had a melting point of 55°C and this fraction turned out to consist of an acid, not hitherto known, its formula being $C_{16}H_{33}COOH$; this fatty acid was termed dorosomic acid.

Another fraction had its melting point at 62.5°C corresponding to palmetic acid, and still another at 69.5°C corresponding to stearic acid. In small quantities, still other fractions were isolated, containing unknown acids.

In later years, the grease of Ca-linh-banh (*Thynnichthys thynnoides* Bleeker), and some other fresh water fish from Cambodia, has been investigated along similar lines (Marcelet, 1940). Dorosomic acid was again detected.

Prospects for technical use.

Possibilities of industrial application have been investigated by Marcelet (1928, b; 1929; 1940).

The low content of unsaponifiable matter of the Ca-moi oil yields a product of high utility value in soap manufacture. It has great drying properties and this makes it valuable as a replacement of linseed oil as the vehicle in paint. It gives satisfactory results in the treatment of leather.

Hydrogenation deodorises the oil easily, and fixes it into a fat suitable for cooking purposes.

Trials have been made to use the product as fuel in diesel motors. In Europe the viscosity caused some inconvenience but later experiments made in the country gave satisfactory results, the tropical temperature making it more fluid. Although the petroleum oils are much cheaper than the oils of fish, it is interesting to note this result in a region such as Indochina which has no natural source of petroleum.

Similar possibilities of technical use have been established for the grease of Ca-linh-banh.

A cracking procedure has been applied in the Ca-moi oil experiments in order to obtain substitutes for petroleum derivates (Chevey, 1934). One trial yielded

25%	benzene
55%	gas-oil
15%	lubricating oil
5%	loss

SECTION III. INDUSTRIAL TRIALS AND BACTERIOLOGICAL RESEARCH.

A. Introduction of Western Industry.

General remarks.

The French government of Indochina was seeking methods of preparing fish quickly and economically which might offer the country products for exportation. Although no success has been attained in building up a profitable industry, the attempts are interesting in connection with the above mentioned investigations because several of the native methods of preparing fish were taken as a guide and the investigations have contributed towards extension of the knowledge of the subject.

Fish oil.

The first attempt to modernize the fisheries industries included the manufacture of fish oil. It was hoped to double the Cambodia fish oil production by a suitable application of modern principles, since by modern procedure twice as much oil might be extracted from the same fish waste as by the old Cambodian methods. Only a small amount of the fish waste of the Great Lake is utilized by the natives, and this circumstance seemed to offer possibilities of increasing production.

The "Société du Grand Lac" tried to operate a floating plant on the lakes (Krempf, 1927, p. 20). In the procedure adopted the freeing of fatty substances was effected by direct contact of steam with the fish enclosed in large autoclaves. The steamed fish was then transferred from the autoclaves into a continuous press in order to separate the solid masses from the liquid portion, that is the water content and the oil. Unexpected difficulties were encountered in the separation of the oil from the water, a persistent emulsion hindering the manufacture.

On examination, one of the causes of this failure proved to be the emulsifying property of the contents of the intestinal tract of mud eating fish of the lakes used for the preparation. Although the method had previously given quite satisfactory results in Europe for the reduction of herring oil, this and any other wet procedure is doomed to failure applied on the lakes of Cambodia. For this reason possibilities here were restricted to methods involving an initial drying of the fish; separation of the oil was then carried out by pressure at a temperature of 80°C. and a subsequent almost complete chemical extraction by trichloro-ethylene or other solvents that could be easily regained.

The steam-heated drier was provided with a central shaft, to which stirrer blades were fixed. The fish waste was dried and at the same time pulverised by the combined action of heat and mechanical agitation, the intestines being transformed into a blackish powder from which the oil could be extracted at any time afterwards.

Fish meal.

When the whole fresh fat fish is used, a 3 hour treatment by the method described above yields a white mass, occasionally containing 40 to 50% of fat. Since the product contains only 10% moisture, it may be stored for a considerable length of time, if properly protected against mites and insects. In order to prevent the fatty substances becoming rancid, limited contact with the air is recommended. After extraction of the oil and suitable refinement of the stock, a fish meal remains which is suitable for human consumption, and is not to be regarded as a waste product.

Thus the primary interest was diverted from the oil and centered on the preparation of fish meal. In subsequent trials the meal was therefore prepared from non-oily fish, the procedure being simpler without fat extraction. Before processing, the fish were usually cut in two oblique longitudinal sections so that one part consisted of the head and viscera and the other of the musculature of the back and the tail (Krempf, 1925, 1934). The head and viscera were kept apart for other use, and only the fleshy parts were worked up to fish meal.

Autolysate.

As a supplement to the above work, an effort was made to develop a method of preparing autolysate in which the solvent action of the juices from the viscera should be more intensive than in the nuoc-mam procedure, so that the preparation time should thereby be shortened. Since it has been demonstrated that the autolytic action of the enzymes was reduced to one third by the customary quantity of salt, attempts were made to replace the salt by some other anti-putrefactive substance. This might have brought with it the advantage that the product could be used as a principal article of diet, which is not the case with the original nuoc-mam because of its high salt content (Krempf, 1925, p. 14).

The first experiments were made with chloroform, but later nitrochloroform (= "chloropicrin"—CCl_3NO_2) was chosen as being more suitable. Since this is one of the most active military gases, great care must be taken in making such experiments. The authors claim to have been able to obtain complete sterilisation by the application of nitrochloroform without hindering autolysis in any way. The volatility of the preservative had the advantage that

it could be driven off readily by evaporating under low pressure, as soon as its presence was no longer required (Krempf, brevet d'invention 571.118).

The head and viscera were kept separate from the fish meal preparation, then ground and left to autolyse as they would with 2 to $3^0/_{00}$ of nitrochloroform. In this manner as much protein was dissolved in five days as required months in the native process. After two weeks the solution contained 1½ times as much autolysed products as good nuoc-mam that conforms to the legal requirements (Boez & Guillerm, 1930, b, p. 1056, c, p. 20). The autolysate was then concentrated in vacuo at a low temperature, which drove out the dangerous preservative. When the volume had been reduced to one quarter of its original amount the product is protected by its own amino acid content from further disintegration and is therefore durable (Guillerm, 1928, p. 39).

The autolysate obtained by this sterile process, as well as the fish meal prepared by the heat method, have not been well received by the natives, in spite of the original high expectations. The excellent food value was demonstrated by several tests made in garrisons, hospitals and on estates, but where the choice of food was left free, the powerfully penetrating fishy odour that is typical of the native fish product, proved clearly enough to be more eccept-able.

B. Bacteriology

General remarks.

The failure to find local markets gave impetus to fresh investigations which showed that the characteristic odour so desired by natives was caused by the action of bacteria. In the native preparation of nuoc-mam and pra-hoc from the second day there develops a homogeneous flora of an anaerobic spore former, especially in the fleshy parts of the fish, before a considerable quantity of salt has penetrated. Pickle and viscera, on the other hand, appear to offer no suitable medium for the development of this organism. Isolation of this spore forming organism was rendered somewhat difficult by its anaerobic properties, so that former attempts had remained unsuccessful (Denier, 1915). This must have been one of the reasons that no thought was given for so long to anything except enzyme action. The characteristics of this organism were further studied, but unfortunately not according to the American methods, so that insertion in Bergy's system, which has obtained international validity, is not yet possible. The diagnosis as given by the authors runs as follows (Boëz & Guillerm, 1930, a & c):

Diagnosis of new Clostridium.

Anaerobic rods, Gram positive, sporulating in 5 days in Veillon solution. Spores oval, subterminal, resistant to 5 minutes at 80°C, but killed within 30 minutes at the same temperature.

On Veillon-agar colonies appearing within 24 hours, attaining 2 to 3 mm. in diameter within some days; centre blurred, surrounded by short, bulky and well defined ramifications. Gas within 24 hours and breaking up of the medium in 3 to 4 days. Characteristic smell of nuoc-mam without putrid odour.

Growth abundant at 28°C, even more at 37° and 45°C, still active at 50°C, doubtful at 52°C. On surface under anaerobic conditions, giant colonies of about ? cm. in diameter, much remified.

Beef medium (under vaseline) becoming vivid red in 24 hours, turning slightly brownish after third or fourth day; gas production (several cc.); very active digestion from first day, affecting half of the muscular mass in five days; characteristic odour.

Bouillon Martin under anaerobic conditions: growth, gas production, no indol formed.

Milk: coagulation and progressive digestion.

Coagulated egg-white: active digestion.

No H_2S formed in lead acetate medium, even when hypo is added.

Fermentation of all the sugars tried (glucose, maltose, laevulose, saccharose, mannite), with gas production especially abundant with glucose and maltose.

This diagnosis enables us to recognise the organism as a Clostridium.

Culture media.

Dr. Guillerm kindly procured me the recipes after which he prepared his Martin's and Veillon's culture media.

MARTIN'S DIGEST SOLUTION.

a. Stomach digest solution.

Constituents: Water 1000 cc., chopped hog stomach 200 g.

Preparation: Chop the stomachs of five hogs into small pieces. Mix 200 g. of these pieces, 1000 cc. water and 10 cc. pure HCl at 50°C. Allow to stand at 50°C for 24 hours. Heat at 100°C for half an hour. Strain through a layer of absorbent cotton. Add 10% solution of sodium hydroxide or sodium carbonate to the heated filtrate till litmus paper gives an alkaline reaction. Filter the fluid through paper to clarify. Distribute quantities of 500 cc. in flasks of 1 litre, and sterilise by heating at 115°C for half an hour.

(Compare: Levine & Schoenlin.—A compilation of culture media for the cultivation of micro-organisms.—Monographs systematic bacteriology. Vol. 2, 969 pp.

Williams & Wilkins. 1930. See p. 308 Martin's peptone.).

b. Beef digest solution

Constitutents: Water 1000 cc., Beef 500 g., Sea-salt 5 g.

Preparation: Chop the beef to small pieces. Mix 200 g. of the chopped beef and 1000 cc. water, allow to stand at 50°C for 20 to 24 hours. Strain through a linen, squeeze and catch the fluid. Add 5 g. sea-salt.

c. Final mixture.

Mix 500 cc. stomach digest solution and 500 cc. beef digest solution, heat to 70°C and make slightly alkaline with caustic soda. Sterilise by heating at 115°C for 15 minutes. Filter and distribute in flasks or tubes. Sterilise at 110°C for 20 minutes.

VEILLON'S SOLUTION.

Constituents: Water 1000 cc. glucose 5-15 g. potassium nitrate 1 g.

Preparation: Mix the above constituents. Sterilise below 120°C for 20 minutes. When making Veillon's agar, add agar before sterilising. Dissolve constituents by heating and distribute in large culture tubes. Sterilise below 120°C for 20 minutes. Cool quickly in vertical position under water tap. Inoculate with deep stab. The agar will exclude the air sufficiently to allow anaerobic growth at the bottom of the tube. Picking up the colonies is done with a narrow pipette.

Bacterial metabolism.

The proteolytic action of this newly found Clostridium, has been investigated more closely because of its bearing on the nuoc-mam manufacture. Proteolysis was therefore tested on sterilised fish meat in an equal volume of water under a vaseline layer. Though the published data of this investigation are rather scanty, the authors arrive at the conclusion that, so far as the formation of formal titratable nitrogen is concerned, there is no essential difference between bacterial action and the digestion by enzymes from the muscles and the intestinal tract of the fish. Against this a marked difference seems to be exhibited in the production of volatile bases, as indicated by the proportion of nitrogen from volatile bases to formol titratable nitrogen. This ratio will amount to 50% in the products of bacterial proteolysis, whereas in sterile enzymatic proteolysis, this ratio will range from 10 to 15%.

The analysis of some 200 samples of native nuoc-mam has given ratios ranging from 35 to 60%. This character, together with the characteristic odour of nuoc-mam, shows that besides enzymatic dissolution, bacterial action is also instrumental in the manufacture of native nuoc-mam.

With the preparation of pra-hoc, on the other hand, bacterial action takes place in the first instance owing to the removal of the entrails (Chevey, 1931).

Especially interesting in this connection is the preparation of nuoc-mam in the province of Cantho, in the extreme West of Cochinchina (Chevey, 1931, p. 29). Here the fish are first gutted and then salted, as is the case with preparation of pra-hoc; the fish do not dissolve much, but develop the desired odour. Pineapple juice is then added to effect the digestion of the flesh and thus nuoc-mam is obtained. So here the age-old empiricism of the people cleverly utilizes bacterial and enzymic reactions.

C. Flavouring trials

One thing and another induced the French also to include the bacteria in their process. After expulsion of the nitrochloroform the sterile autolysate was inoculated with the essential microbe, either in pure culture or not, and then tested occasionally for flavour. If, after 24 to 40 hours, the liquid was saturated with salt, the product seemed to be identical with the ordinary nuoc-mam (Krempf, 1929). The preparation of the autolysate took 4 to 5 days and the expulsion of the nitrochloroform but a few minutes so that this might indeed be called a quick process as the native preparation takes months and months (Krempf, brevet d'invention 692.918.)

The manufacture of fish meal was also altered, the stirring being carried out at moderate temperature. The mash resulting from this treatment was still moist from its own water content. It was spread out in the open, and soon the desired odour developed. A fragrant fish meal was then obtained by subsequent drying in the sun or in vacuo at a low temperature.

In order to present an unaccustomed product to the people, it was provided in a familiar form rather than in a powder. The fish meal was therefore mixed with the fermented autolysate which was condensed to a syrup, and this was mixed again with tapioca flour. The flat cheesy lumps were cut into slices, in which form it was presented to the customers at the rate of 1 piaster per kg. A daily ration of 100 g. of this highly nutritive and palatable product was considered to be an ideal supplement to the ordinary menu.

Apart from this, another experiment has been made in France, by treating meat with nuoc-mam (Gauducheau, 1927). Different extracts have been tried to give a special flavour to the flesh, when injected into the arterial system shortly after slaughter. This has been practised with fowls, small game and even sheep. When after killing the bleeding has stopped, the necks are tied off and a quantity of liquid, amounting to 1/20 of the body weight is introduced into the blood vessels by injection. After one or two hours the meat can be dressed and will

be ready for use after one or two days. If the treatment is carried out with a mixture of tomato juice and nuoc-mam, the meat will acquire a gamy high flavour which seems to be much desired in French cookery. The gamy flavour is thus obtained artificially, without the action of putrefactive organisms.

LEGISLATION ON THE MANUFACTURE AND THE TRADE OF NUOC-MAM AND ALLIED PRODUCTS.

1er aout 1905—Loi sur la repression des fraudes dans la vente des marchandises et des falsifications des denrees alimentaires et des produits agricoles; promulguee le 15 decembre 1905, suivie en son article 6 d'une circulaire ministerielle (Justice) en date du 28 decembre 1911 et en son article 11 d'une circulaire du Procureur general en Indochine en date du 22 aout 1912.

Journal Officiel de la Republique Francaise. Paris. Annee 37me, No1, 1906, p. 2.
Journal Officiel de l'Indochine Francaise. Hanoi. Annee 18me, No1, 1906, p. 2.

28 juillet 1912—Loi tendant a modifier et a completer la loi du 1er aout 1905 sur la repression des fraudes dans la vente des marchandises (et de la loi du 29 juin 1907 sur le mouillage et le sucrage des vins).

Journal Officiel de la Republique Francaise. Paris. Annee 44me, No207, 1912, p. 6897-6898.
Annuaire International de Legislation Agricole. Rome. (Institut International d'Agriculture). Annee 2me, (1912) 1913, p. 27-29.

9 avril 1913—Decret rendant applicable en Indochine la loi du 28 juillet 1912 (promulgue le 12 juin 1913).

Journal Officiel de l'Indochine Francaise. Hanoi. Annee 25me, No.., 1913, p. 1038.

21 avril 1915—Decret rendant applicables en Indochine divers lois et decrets sur la repression des fraudes dans la vente des marchandises et des falsifications des denrees alimentaires et des produits agricoles (promulgue le 16 juin 1915).

Journal Officiel de l'Indochine Francaise. Hanoi. Annee 27me, No49, 1915, p. 1034.

21 decembre 1916—Arrete du Gouverneur General reglementant la vente du nuoc-mam, suivi, en note, de la methode d'analyse du nuoc-mam a l'usage des laboratoires agres en Indochine pour la repression des fraudes sur les denrees alimentaires.

Journal Officiel de l'Indochine Francaise. Hanoi. Annee 28me, No103, 1916, p. 1987-1988.
Archives des Instituts Pasteur d'Indochine. Saigon. Tome 2, No7, (IVme Annee), 1928, p. 47-49.

6 mai 1919—Loi relative a la protection des appellations d'origine.

Journal Officiel de la Republique Francaise. Paris. Anne 51me, No125, p. 4726-4727.
Annuaire International de Legislation Agricole. Rome. (Institut International d'Agriculture). Annee 9me, (1919) 1920, p. 198-202.

8 decembre 1924—Arrete du Gouverneur General completant l'article 3, modifiant l'article 4 de l'arrete du 21 decembre 1916 reglementant la vente du nuoc-mam.

Journal Officiel de l'Indochine Francaise. Hanoi. Annee 36me, No100, 1924, p. 2373.
Archives des Instituts Pasteur d'Indochine. Saigon. Tome 2, No7, (1Vme Annee), 1928, p. 49-50.

23 Novembre 1926—Arrete du Gouverneur General suspendant au Tonkin et dans le Nord-Annam (province Thanh-Hoa a Quang-Tri inclus) l'application des dispositions des arretes des 21 decembre 1916 et 8 decembre 1924 reglementant la vente du nuoc-mam et du nuoc-nhut.

Journal Officiel de l'Indochine Francaise. Hanoi. Annee 38me, No95, 1926, p. 3179.
Archives des Instituts Pasteur d'Indochine. Saigon. Tome 2, No7 (IVme Annee), 1928, p. 50.

17 aout 1928—Decret portant reglement d'administration publique pour l'application en Indochine de la loi du 1er aout 1905 sur la repression des fraudes (promulgue le 11 octobre 1928).

Journal Officiel de la Republique Francaise. Paris. Annee 60me, No197, 1928, p. 9604-9607.

5 decembre 1929—Arrete au sujet des conditions d'application du decret du 17 aout 1928, relatif au service de recherche et de constatation des fraudes.

Bulletin Administratif de la Cochinchine. Saigon. Annee 29me, No3, 1930.

18 avril 1930—Arrete abrogeant et remplacant les arretes des 21 decembre 1916, 8 decembre 1924 et 23 novembre 1926, portant definition legale du nuoc-mam et reglementation de la vente de ce produit.

Journal Officiel de l'Indochine Francaise. Hanoi. Annee 42me, No36, 1930, p. 1527.

26 decembre 1930—Circulaire du Gouverneur de la Cochinchine au sujet de la repression des fraudes sur le nuoc-mam.

Bulletin Administratif de la Cochinchine. Saigon. Anne 29me, 1930, p. 3311.

2 decembre 1931—Arrete du Gouverneur General modifiant l'arrete du 18 avril 1930 portant definition legale du nuoc-mam ou nuoc-nhut.

Journal Officiel de l'Indochine Francaise. Hanoi. Annee 43me, No99, 1931, p. 4178.

28 juin 1932—Circulaire du Gouverneur General au sujet de la fraude sur le nuoc-mam.

Bulletin Administratif de la Cochinchine. Saigon. Annee 31me, 1932, p. 1454.

26 avril 1933—Decret portant definition legale du nuoc-mam et du nuoc-nhut et determination des conditions de vente de ces produits (promulgue le 1er juin 1933).

Journal Officiel de la Republique Francaise. Paris. Annee 65me, No103, 1933, p. 4588-4590.
Journal Officiel de l'Indochine Francaise. Hanoi. Annee 45me, No46, 1933, pfl 1866.
Annales des Falsifications et des Fraudes. Paris. Annee 26me, No298, 1933, p. 305-306.

13 octobre 1933—Arrete du Gouverneur General admettant certaines tolerances pour les nuoc-nhut et les nuoc-mam.

Journal Officiel de l'Indochine Francaise. Hanoi. Anne 45me, No83, 1933, p. 3411.

19 novembre 1934—Arrete approuve par le Ministre des colonies, determinant les produits chimiques et les matieres colorantes dont l'emploi est autorise en Indochine pour la conservation ou pour la coloration des marchandises et des denrees destinees a l'alimentation ainsi que les conditions auxquelles reste subordonne l'emploi des dites substances.

Journal Officiel de l'Indochine Francaise. Hanoi Annee 47me, No39, 1935, p. 1930.

23 decembre 1935—Ordonnance royale au Cambodge No226. Vente du nuoc-mam au Cambodge.

Bulletin Administratif du Cambodge. Pnom-Penh. Annee 35me, No2, 1936, p. 148-150.

2 juillet 1937—Décret modifiant l'article 6 du decret du 26 avril 1933 portant reglement d'administration publique pour la definition legale du nuoc-mam et du nuoc-nhut et la determination des conditions de la vente de ces produits (promulgue le 31 juillet 1937).

Journal Officiel de l'Indochine Francaise. Hanoi. Annee 49me, No64, 1937, p. 2366.

25 aout 1937—Decret portant approbation de la Deliberation du 21 avril 1937 par laquelle la Commision permanente du Conseil de Gouvernement de l'Indochine a demande la suppression des droits de sortie sur les pates et saumures de poissons exportes de la colonie a destination des pays etrangers (promulgue le 19 octobre 1937).

Journal Officiel de l'Indochine Francaise. Hanoi. Annee 49me, No86, 1937, p. 3157.

14 janvier 1938—Arrete du Gouverneur General instituant une Commission consultative chargee d'etudier les textes reglementant le commerce du nuoc-mam et de proposer les mesures propres a assurer leur application.

Journal Officiel de l'Indochine Francaise. Hanoi. Annee 50me, No6, 1938, p. 377.

12 octobre 1938—Decision du Directeur des Douanes et Regies fixant le prix de vente du sel de Baria destine a l'industrie saumuriere et la preparation des poissons sales a Hone Cone, Cheko et Snam Crabeu.

Journal Officiel de l'Indochine Francaise. Hanoi. Annee 50me, No84, 1938, p. 3614.

14 avril 1939—Loi ratifiant le decret du 25 aout 1937 portant suppression en Indochine des droits de sortie sur les pates et saumures de poissons (promulgue le 13 mai 1939).

Journal Officiel de l'Indochine Francaise. Hanoi. Annee 51me, No38, 1939, p. 1341.

PATENTS ON THE PRODUCTION OF AUTOLYSATES WITH NITROCHLOROFORM.

B.F. : Brevet francais.
B.P. : British Patent.
U.S.P. : United States Patent.
D.R.P. : Deutsches Reichs Patent.

B.F. 571.118 26 janvier 1924.

Procede de preparation et d'extraction industrielles de derives azotes utilisables et de matieres grasses par digestion artificielle, applicable aux poissons, aux dechets de poissons et d'une maniere generale aux produits et dechets organiques d'origine animale.
A. Krempf.

B.P. 208.144 February 12, 1925.

Improved treatment of protein of animal origin for industrial purposes.
A. Krempf.

U.S.P. 1.602.029 October 5, 1926.

Process of treating protein material.
Societe Civile d'Etudes des Produits de la Mer
A. Krempf.

D.R.P. 453.642 12 Dezember 1927.

Verfahren zur Gewinnung von Eiweissabbauprodukten und Fettstoffen aus Eiweissstoffen tierischen Ursprungs.
La Societe Civile d'Etudes des Produits de la Mer.

B.F. 692.918 11 aout 1930.

Procede de fabrication de produits alimentaires obtenus par autolyse des corps proteiques.
A. Krempf.

BIBLIOGRAPHY.

AUTRET, M. & A. Vialard-Goudou, (1939).—Les acides amines du nuoc-man. Ire note: Le tryptophane dans le nuoc-mam. *Revue Medicale Francaise d'Extreme Orient*, Hanoi. Annee 1939, No8, p. 1031-1038.

———— (1940).—Les acides amines du nuoc-mam. 2e note: Elimination du sel. *Idem*, Annee 1940, No4-5, p. 198-202.

BAURAC, J. C., (1898).—Courtes notices sur l'Indochine. II. Les pecheries. *Bull. Soc. Etudes Indochinoises de Saigon*, No36, Fasc. 1, p. 36-38.

BERNARD, Noel, (1922).—see GUILLERM, J.

BOEZ, L. & J. Guillerm, (1930).—Le facteur microbien dans la fabrication de la saumure indochinoise (nuoc-mam). *Compt. Rend. Acad. Sci.*, Tome 190. No8, 534-535.

———— (1930).—Pouvoir proteolytique de la flore anaerobie de la saumure indochinoise (nuoc-mam). *Compt. Rend. Soc. Biol.*, 103: 1054-1056.

———— (1930).—Le facteur microbien dans la fabrication du nuoc-mam. *Arch. Inst. Pasteur d'Indochine*. Tome 3, No11, (VIme Année), p. 17-21.

BREMOND, H. M. L., (1918).—see Rose, E. & H. M. L. Bremond.

———— ———— (1919).—Recherches sur quelques condiment azotes d'Extreme-Orient. These pour le doctorat de l'Universite de Bordeaux. Faculte de Medecine et de Pharmacie. Annee 1918-1919, No74, 82 pp. Impr. Gounouilhou. 9-11 rue Guidaude, Bordeaux.

BREMOND, H. M. L. & F. Rose, (1919).—Condiments azotes solides en Indochine. *Annal. Inst. Pasteur, Paris.* 33: 282-291.

BREYMANN, G., (1902).—La Peche en Indochine. *Bull. Econ. Indochine*, Hanoi. Annee 5me Nouv. Serie, No6. p. 379-392.

CAMPOBASSO, (1912).—see DELOCHE DE CAMPOBASSO.

———— (1923).—see DELOHE DE CAMPOBASSO.

CAPUS, G. & D. Bois, (1912).—Les produits coloniaux. 1 Vol. in 8°, VIII-657 pp. Librairie Arm. Colin. Paris. (Partie 2me, Produits du regne animal; Produits des Pecheries; Pecheries de l'Indochine. p. 584-589).

CHAT, TRAN VAN, (1922).—See TRAN VAN CHAT.

CHEVEY, P., (1929).—OEuvre ichthyologique de G. Tirant. Reimpression. Station maritime de Cauda. Service

Oceanographique des Peches de l'Indochine, Saigon. *Notes.* N°6, 175 pp.

———— (1931).—Rapport sur le fonctionnement de l'Institut Oceanographique de l'Indochine pour l'annee 1930-1931. *Idem.* N°18, 34 pp.

———— (1933).—Idem, pour l'annee 1931-1932. *Idem,* N°21, 22 pp. + 2 graph.

———— (1934).—Idem, pour l'annee 1933-1934. *Idem,* N°24, 21 pp + 11 planches.

CHEVEY, P. & J. Lemasson, (1937).—Contribution a l'etude des poissons des eaux douces tonkinoises. *Idem,* N°33. 183 pp.

CHEVEY, P. & F. Le Poulain, (1939).—Rapport preliminaire sur la peche dans les eaux douces cambodgiennes. *Bull. Econ. Indochine,* Hanoi. Annee 42me Fascicule 1 & 2, p. 39-83; 260-331, + pl. I-XVI + croquis 1-9.

———— (1940).—La peche dans eaux douces du Cambodge. Trav. Service Oceanographique des Peches de l'Indochine. Saigon. *Memoire* 5me, Partie Ire, 193 pp. + 48 pl.

COMPAGNIE DES GRANDS LACS, (1925).—L'industrie de la peche an Cambodge. 33 pp. Imprimerie nouvelle Alb. Portail, 185-189 rue Catinat. Saigon.

CORDEMOY, (1903).—see Jacob de Cordemoy, H.

———— (1932).—Le nuoc mam. *Bull. Agence Econ. Indochine.* Annee 4me, Nouv. Serie, N°54, p. 200-205.

COTTE, J., (1906).—see G. Darboux, J. Cotte, P. Stephan & F. van Gaver.

DANG-VAN-TIEN, (1941).—see Vialard-Goudou, A & Dang-van-Tien.

DARBOUX, G., J. Cotte, P. Stephen & F. van Gaver, (1906).—L'industrie des peches aux colonies. 2 vol. 19 28, 261 & 516 pp. Paru a l'occasion de l'Exposition Coloniale a Marseille en 1906. Barlatier, Imprimeur-Editeur, 17-19 rue Venture. Maseille.

DELOCHE DE CAMPOBASSO, (1922).—Les productions du Cambodge, notice commercielle et industrielle.

DELOCHE DE CAMPOBASSO, (1923).—Le Cambodge economique. 17x25, 57 pp.—1 carte. Imp. d'Extreme-Orient. Hanoi.

DENIER, (1915).—Etude bacteriologique de nuoc-mam. Rapport pour le Conseil Superieur de l'Indochine. Octobre 1915. Unpublished report.

DEVRAIGNE, (1917).—L'Indochine economique. Son mouvement commercial. Ses principaux produits naturels.

FINELLE, (1923).—Huile des poissons. Annexe N°24, a un Rapport inedit, depose dans les Archives de la Residence superieure du Cambodge. Phnom-Penh.

FROIDEVAUX, J., (1926).—Le nuoc-mam. Condiment annamite. *Annales des Falsifications et des Fraudes.* Paris. Anne 19me, N°210, p. 326-334.

GAUDUCHEAU, A., (1927) & (1928).—L'embaumement des viandes, Le traitement des viandes par voie sanguine. Les intrasauces. *Revue Generale des Sciences pures et appliquees.* Paris. 31 decembre 1927.
Annales des Falsifications et des Fraudes. Paris. Annee 21me, N°230, p. 84-90, 1928.

GAVER, F. VAN, (1906).—See G. Darboux, J. Cotte, P. Stephan & F. van Gaver.

GENEVARAY, J., (1934).—See Morin, H. G. S., H. Jacotot & J. Genevray.

GOUROU, P., (1930).—L'Institut Oceanographique (de l'Indochine) et les conditions de peche en Asie tropicale. *Revue Indochinoise Illustree.* Editions d'Extreme Oriet. Saigon. p. 14-16. Extreme Asie. Saigon. N°49, p. 352-354.

GRUVEL, A., (1924).—L'Organisation du service oceanographique applique l'industrie des peche en Indochine. *Le Monde Colonial Illustre,* octobre 1924.

———— (1925).—L'Indo-Chine. Ses richesses marines et fluviales.
16x25, 319 pp.—XXVI pl. Societe d'Editions Geographiques Maritimes et Coloniales (Ancienne Librairie Challamel) 17 rue Jacob, Paris (VIme).

GUILBERT, L., (1916).—La peche dans le golfe du Tonkin. *Bull. Econ. d'Indochine,* Hanoi. Annee 19me Nouv. Serie, N°118, p. 133-191 + 1 tabl. + 1 croquis.

GUILLERM, J., (1922).—Les condiments azotes indochinois. P. Noel BERNARD—Les Instituts Pasteur d'Indochine (Centenaire de Louis Pasteur 1822-1895), 249 pp. Imprimerie Nouvelle Alb. Portal, 185-189 rue Catinat, Saigon, 1922. p. 215-219.

———— (1928).—Le nuoc-mam et l'industrie saumuriere en Indochine. *Arch. Inst. Pasteur d'Indochine,* Tome 2, N°7, (IVme Année), p. 21-60.

———— (1930).—see Boez, L. & J. Guillerm.

———— (1930).—L'explication scientifique d'un phenomene, empirique, la production du nuoc-mam. *Trans. 8th Cong. Far East. Assoc. Trop. Med.,* 1930. Bangkok. 1: 122-132.

———— (1931).—L'industrie du nuoc-mam en Indochine. Exposition Coloniale Internationale a Paris en 1931. Indochine Francaise. Section Scientifique. Instituts Pasteur d'Indochine. Publie hors de volume. 36 pp. Imprimerie nouvelle Alb. Portail, 185-189 rue Catinat. Saigon.

JACOB DE CORDEMOY, H., (1903).—Les produits coloniaux d'origine anamale.
I Vol. in 8°, VII + 396 pp. Librairie J. B. Bailliere & fils. Paris.

JACOTOT, H., (1934).—See Morin, H. G. S. H. Jacotot & J Genevray.

JASINSKY, R., (1932).—Le peche maritime en Cochinchine. *La Revue de Pacifique,* N°9, p. 288-292.

KREMPF, A., (1926).—Rapport sur le fonctionnement du Service Oceanographique des Peches de l'Indochine pendant l'annee 1924-1925. Station maritime de Cauda. Service Oceanographique des Peches de l'Indochine. Saigon. *Notes* N°2, 16 pp.

———— (1926).—Idem. pour l'annee 1925-1926. *Idem.* N°5, 22 pp.

———— (1927).— Idem, pour l'anne 1926-1927. *Idem.* N°9, 23 pp.

———— (1928).—Idem, pour l'annee 1927-1928. *Idem.* N°11, 32 pp.

———— (1929).—Idem, pour l'annee 1928-1939. *Idem,* N° 13, 43 pp.

———— (1931).—Travaux de l'Institut Oceanographique. Resultats acquis jusqu'en 1931. Recherches techniques. Traitement industriel du poisson.
Exposition Coloniale Internationale a Paris en 1931. Indochine Francaise. Section Scientifique. Compte Rendu des Ouvrages de l'Indochine, paru a l'"occasion de l'———. Imprimerie d'Extreme Orient. Hanoi. p 22-24.

———— (1934) & (1936).—Preservation and utilisation of fish products in the tropics.
Proc. Fifth Pac. Sci. Cong., Canada, 1933 Univ. Press, Toronto. 5: 3693-3697, 1934. [Also, Station maritime de Cauda. Institut Oceanographique de l'Indochine. (Service Oceanographique des Peches de l'Indochine). Saigon. *Notes* N°29, p. 31-37.

LABIGOTRYE, H. DE. (1919).—Le nuoc-mam indochinois. *Gazette coloniale,* du 4 avri, p. 1.
For extract see: *Annales des Falsifications et des Fraudes,* Paris. Annee 12me, p. 236. 1919.

LEBAS, J., (1925).—Les pecheries du Tonle Sap (Cambodge). *Annal. geogr.* 34: 69-73.

LEGRAND DE LA LIRAYE, T. M., (1869).—Notes sur divers produits de la Cochinchine destines a l'Exposition Coloniale: Nuoc-mam. *Bull. Comite Agris. Ind.* Cochin-chine, Tome 2, N°8, 50-54. Reprinted: Paris 187..

LEMASSON, J., (1937).—See Chevey, P. & J. Lemasson.

LEONARD, (1880).—Notes sur l'huile de poisson provenant de la derniere peche faite a Phnom-Penh. *Excursions et Reconnaissances.* Saigon N° 6, p. 403-404.

MARCELET, H., (1928).—Presence d'un acide gras, non encore observe, dans une huile.
Compt. Rend. Acad. Sci. Tome 187, N°2, p. 145-146.

———— (1928). Utilisation das hiles d'animaux marine dans les moteurs. *Chimie et Industrie,* Tome 20, N°5, p. 829-836.

———— (1929) & (1931).—L'huile de Ca-Moi (Dorasoma nasus Bl.). Etude physico-chimique.
Station maritime de Cauda. Service Oceanographique des Peches de l'Indochine. Saigon *Notes.* N°12, 57 pp. 1929.

[Also in: Exposition Coloniale Internationale a Paris en 1931. Indochine Francaise. Section Scientifique, Compte Rendu des Ouvrages de l'Institut Oceanographique de l'Indochine, paru a l'occasion de l'———. Imprimerie d'Extreme Orient. Hanoi. 1931].

———— (1940).—La graisse du Ca linh banh (*Thynnichthys thynnoides* Bleeker). Etude physicochimique. *Idem,* N°37, 27 pp.

MARON, F., (1939).—Le commerce du poisson sec aux Indes Neerlandaises. *Bull. Econ. Indochine.* Hanoi. Annee 42me, Fasc. 2, p. 365-374.

MARRE, F., (1920).—Le nuoc-mam.
L'Opinion, Journal independant. Imprimerie Nouvelle Claude & Cie., 13-15 rue Catinat, Saigon. Annee 25me, 18 decembre.

MERLE, A., (1880).—Le nuoc-mam.
Bull. Sec. Geogr. Comm. Bordeaux. Tome?, p. 413-418.

MESNARD, J. & E. Rose, (1920).—Recherches complementaires sur la fabrication du nuoc-mam. *Annal. Inst. Pasteur,* Paris. 34:622-649.

MORIN, H. G. S., H. Jacotot & J. Genevray, (1934).—Les Instituts Pasteur d'Indochine en 1934. *Arch. Inst. Pasteur d'Indochine.* Tome 5, N°20, (Xme Année), p. 425-517.

NGUYEN-KIM-KINH, (1933).—See Peirier, J. C. & Nguyen-Kim-Kinh.

PEIRIER, J. C. & Nguyen-Kim-Kinh., (1933).—Dosage rapide deu acides amines et des polypeptides dans le nuoc-mam. *Annales des Falsifications et des Fraudes.* Paris. Annee 26me, N°289, p. 6-18.

PETILLOT, L., (1911).—Une richesse du Cambodge, la peche et les poissons 16x24. 167 pp. Societe d'editions Geographiques, Maritimes et Coloniales (Ancienne librarie Challamel) rue Jacob, Paris.

POULAIN, F. LE, (1938).—Le prahoe. *Bull. Econ. Indochine,* Hanoi. Annee 41me, Fasc. 2, p. 329-334.
Bull. Soc. Centrale Aquicul. et Peche. Tome 45, N°7-9, p. 78-83.

———— (1939).—See Chevey, P. & F. le Poulain.

———— (1940).—See Chevey, P. & F. le Poulain.

ROBEQUAIN, CH., (1930).—L'OEuvre du service oceanographique et l'avenir des industries de la peche en Indochine. *Bull. Agence Econ. d'Indochine.* Année 2me, Nouv. Serie, N°28, p. 113-116.

ROSE. E.. (1918a).—Recherches sur la fabrication et la composition chimique du nuoc-mam. *Bull. Econ. d'Indochine,* Hanoi. Annee 21me, Nouve. Serie, N°129, p. 155-217.

———— (1918b).—Etude comparee de diverse sauces alimentairs europeens et sino-annamites.
Bull. Econ. d'Indochine, Hanoi. Annee 21me, Nouv. Serie, N°131, p. 525-532.

———— (1918c).—Le nuoc-mam de Nord (Centre-Annam et Tonkin). Composition chimique et fabrication. *Bull. Econ. d'Indochine,* Hanoi.
Annee 21me, Nouv. Serie, N°132, p. 955-973.

———— (1918d).—Le nuoc-mam (eau de poisson), condiment national indochinois, source economique de matiere azotee.
Bulletin, Gouvernement General de 'Indochine, Serie Saigon. N°4, 18 pp. Imprimeur-editeur C. Ardin & Fils. Saigon.

Congres d'Agriculture Coloniale organise par l'Union Coloniale Francaise a Paris en 1918 sous la presidence de M. J. Chailley, Section des Pecheries Coloniales. Publie hors de volume. 18 pp.

———— (1919).—Le nuoc-mam. Condiment national indochinois. *Annal. Inst. Pasteur,* Paris. 33:275-281.

———— (1919).—See Bremond, H. M. L. & E. Rose.

———— (1919).—Etude comparee de diverses sauces alimentaires. *Annal. Inst. Pasteur,* Paris. 33:292-300.

———— (1919).—Note au sujet du nuoc-mam condense. *Bull. Econ. d'Indochine,* Hanoi.
Annee 22me, Nouv. Serie, N°134, p. 75-82.

———— (1920).—See Mesnard, J. & E. Rose.

———— (1921).—Un mode indochinois d'utilisation du poisson: "le nuoc mam".
Bull. Soc. Sci. Hygiene alimentaire, et d'Alimentation rationelle de l'Homme, 9:547.

———— (1925).—Etudes sur le nuoc-mam.
Annal. Med. Pharm. Col., Tome....., p. 5....

ROSE, E., & H. M. L. Bremond, (1918).—Condiments azotes solides en Indochine. *Bull. Econ. d'Indochine,* Hanoi. Annee 21me, Nouv. Serie, N°133, p. 1024-1032.

ROUAN, J., (1929).—La peche en Indochine.
La Nature, Revue des Science et de leurs applications aux arts et a l'industrie. Paris. N°2816, p. 195-204.

SCHROEDER, K., (1869).—Notes sur divers produits de la Cochinchine destines a l'Exposition Colonial: Le poisson salé sec. *Bull. Comité Agric. Ind. Codhinchine.* Paris. Tome 2, N°8, p. 40-42. Reprinted: Paris 1872.

STEPHAN. P., (1906).—See Darboux, G., J. Cotte, P. Stephan & G. van Gaver.

TIEN, DANG-VAN, (1941).—See Vialard-Goudou & Dang-van-tien.

TIRANT, G., (1885).—Note sur les poissons de la Basse-Cochinchine et du Cambodge. Excursional et Reconnaissances, Saigon.
N°22, p. 413-438; N°23, p. 91-198.

TRAN VAN CHAT, (1922).—La peche aux poissons et la fabrication du "nuoc-mam" (saumure) sur les cotes de l'Annam. 28 pp. Imprimerie de la Societe du "Petit Marseillais", Marseille.

VEEN, A. G. van, (1941).—Jaarverslag over 1939 van Eykmaninstituut, Batavia, B. Chermische Afdeeling.—*Mededeelingen van den Dienst der Volksgezondheid in Nederlandsch India.* Jaargang 30, N°1/2, p. 32-59.

VIALARD-GOUDOU, A., (1939).—See Autet, M. & A. Vialard-Goudou.

———— (1940).—See Autret, M. & A. Vialard-Goudou.

VIALARD-GOUDOU, A., & Dang-van-tien, (1941).—Les composants mineraux du nuoc-mam. I. Soufre mineral et soufre organique.
Revue Medicale Francaise d'Extreme Orient, Hanoi. Anne 1940, N°8, p. 547-552.

VILLAREM, G., (1905).—Pecheries du Tonkin.
31 pp. Edition Gallois. Haipong.

WESTENBERG, J., (1941).—De visscherij-producten van Indochina.
Mededeelingen van de Onderafdeeling Zeevisscherij van het Department van Economische Zaken. Batavia. N°6, p. 16-57.

13

ABSTRACTS OF PAPERS PRESENTED AT THE MEETING BUT PUBLISHED ELSEWHERE

HYDROLOGY

VEEN, P. Ch. : "Monthly mean surface salinities in the Indonesian Archipelago"

Published in *O.S.R. News Indonesia,* June 1950: 2:66-68

PLANKTOLOGY

BLACHE, J. : "Notes on the Fresh-water Surface Plankton of Cambodia"

Published by the Fisheries Research Institute, Pnom-Penh, Indo-china.

The hydrographical network of Cambodia comprises the Great Lake (whose level and area fluctuate annually), the Tonle Sap, and the preks. The plankton of these types of water is described; that of the Great Lake is described as being of the baltic eutrophic type. The composition and distribution of the plankton populations of the different types of water are decsribed and the relationship of the plankton to the fish populations is discussed with the conclusion that this freshwater plankton exercises considerable influence over the fish population.

BLACHE, J. : "Notes and observations on the standardization of methods in work on plankton of continental waters (à propos Dr. Thompson's Note.")

To be published by Fisheries Research Institute, Phnom-penh, Indo-china.

Reasons are advanced for considering it difficult if not impossible to apply in continental waters the methods employed in the open sea for the collection of plankton; a reservation is made however in respect of the Hardy indicator. On the other hand support is offered to the proposal for standardisation of methods of examination of plankton and those for the graphical representation of results. A description is given of the methods employed in Indo-China.

BIOLOGY

SERVENTY, D. L. : The Tuna Resources of Australia—Abridged Report.

This paper is an abridgement of a detailed paper which gives taxonomic description of the important species of tuna occurring in Australian waters, with an account of their distribution. Relevant information under food and gear technology is also furnished.

The species listed are: *Thunnus thynnus maccoyii, Katsuwonus pelamis, Kishinoella tonggol—Neothunnus rarus, Euthynnus alletteratus, Sarda chiliensis australis, Sarda orientalis, Cybiosarda elegans, Thunnus germo, Neothunnus macropterus, Gymnosarda nuda, Allothunnus fallai.*

SCHUSTER, W. H.: "Comments on the Importation and Transplantation of Different Species of Fish into Indonesia"

An account is given of the introduction to Indonesia of various species of fish from numerous parts of the world, and of transplantation as between parts of the archipelago. The records go back at least fifty five years. The effect of these activities is discussed. A list of autochthonous fish is given with a discussion of the autochthonous fish fauna of the three major divisions of the archipelago, viz. the Sunda Shelf, the Intermediate Zone (Wallova) and the Sahul Shelf. The environmental requirements of cultivated fish are discussed.

RABANAL, H. R., H. R. MONTALBAN & D. K. VILLALUZ: "The Preparation and Management of the Bangos Fishpond Nursery in Philippines"

To be published in "Philippine Journal of Fisheries"

The cultivation of bangos or milkfish, *Chanos chanos*, is a lucrative and highly developed industry in the Philippines. Much of the success of the operations depends upon the preparation and management of the nursery ponds: the factors which must be considered in selecting a site for these ponds and the precautions which must be taken in constructing them are described. The methods of sorting fry, stocking, rearing and transplantation are described.

THOMSON, J. M.: "Australian Oyster Stocks"

A brief review is given of the operations in commercial production of oysters of various species in Australian waters and of the trial shipments of oysters from Japan.

BLANCO, G. J., D. K. VILLALUZ & H. R. MONTALBAN:" The Cultivation and Biology of Oysters at Bacoor Bay Luzon"

To be published in "Philippine Journal of Fisheries"

This paper reports the stick, hanging and tray methods of oyster culture undertaken in the Bureau of Fisheries one-hectare oyster experimental farm at sitio Binakayan, Kawit, Cavite, Bacoor Bay, a small cove of Manila Bay. Such methods are now popularly adopted by private oyster farmers within Bacoor Bay; Paranaque, Dagat-dagatan Lagoon, Rizal; Binmalay, Pangasinan and Iwahig Penal Oyster Farm, Palawan. Included in this work are descriptions of some twelve species of oysters so far recorded in the Philippines, together with a brief discussion of the biology of oysters.

VILLADOLID, D. V. & D. K. VILLALUZ: "The Cultivation of Sugpo, *Penaeus monodon* Fabricius, in the Philippines"

To be published in "Philippine Journal of Fisheries"

A kind of shrimp known as sugpo and called scientifically *Penaeus monodon* Fabricius is being cultivated in Philippine estuarine fishponds in commercial scale. The sugpo fry, which are almost black except the dorso-median longitudinal plane which is light brown, generally appear in abundance from May to October of each year along the sea-coast especially near the mouths of tidal rivers, creeks and lagoons where the water is brackish. Sugpo fry are collected from these places and planted in well constructed fishpond where they are raised to marketable size of not less than ten inches long after six months. While in captivity, the sugpo fry feed on plankton (lab-lab) in the nursery ponds and on algae (lumut) in the rearing ponds. A hectare of fishpond on the average produces around three hundred and fifty kilos of marketable sugpo.

MADERAZO, C. Y.: "A Guide to the Recognition of Fishes Caught with the Use of Explosives"

To be published in "Philippine Journal of Fisheries"

To combat the destruction of aquatic resources through the use of explosives in fishing the Philippine Bureau of Fisheries has prepared a general publication

with pointers on the recognition of fishes that have been caught in such manner. Various external and internal changes in the anatomy of dynamited fish are enumerated.

THOMSON, J. M.: "The Australian Mullet Fishery"

A brief review is given of the biology of mullet, of various species, in Australian waters and of the commercial fisheries for these species.

LE MARE, D. W.: "Kembong Landings"

Monthly statistics of landings of Kembong in certain states of Malaya during recent years are presented and briefly discussed.

BLANCO, G. J., & D. V. VILLADOLID: "The Young of some Fish of Luzon"

To be published in "Philippine Journal of Fisheries"

The utilization of milkfish fry *kawag-kawag*, *Chanos chanos* (Forskal) and kitang *Scatophagus argus* Linnaeus, for stocking brackish water fishponds is an immense industry worth over 1.000,000 pesos annually to the municipalities of the Philippines which has sandy seacoasts, small coves, mouth of rivers and tidal estuaries. Although the catching of larval gobies (*ipon*) Gobiidae and signaid fry (*padas*) Teuthidae for the manufacture of bagoong (salted fish paste) are also very significant in the fishery economy of the Philippines, the wholesale capture of *kawag-kawag*, *ipon*, *padas* and a considerable number of the juvenile of marine as well as brackish and freshwater species oof fish periodically, account for the apparent scarcity or depletion of the commercial species of fishes of the Philippines. It is due to this unregulated catching and utilization of young fishes, that this present taxonomic work has been undertaken. It is hoped this work may become the basis for a thorough systematic classification of the food fishes in our country, paving the way for further inquiries on other aspects of fisheries biology which may lead to the formulation of remedial measures to protect and conserve the fishery resources of the Philippines from depletion.

HARDENBERG, J. D. F.: "Taxonomy"

As part of the programme of Technical Committee I for 1949/50 a synopsis of the species of Scomber and Rastrelliger from Indo-Australian Seas (after de Beaufort) and a key for the identification of tunas and allied genera in these waters is submitted together with notes on the systematic study of the Philippine Chub Mackerels, Family Scombridae, Genera Rastrelliger and Scomber, by Porfirio Manacop, Aquatic Biologist of the Philippine Fishery Programme of the U.S. Fish and Wildlife Service.

GEAR TECHNOLOGY

SERENE, R.: "Le Peche aux Requins en Indochine"

To be published by Oceanographic Institute, Nha Trang, Indo-china.

The fishing methods, catch etc. employed in the Indo-Chinese Shark-fishery are described, by regions; particular attention is paid to the economics of the industry. The production and utilisation of shark flesh, shark-skin, fins, liver oil and so forth are described.

KESTEVEN, G. L.: "Report on the Fisheries of Pakistan"

Published by Civil & Military Gazette, Karachi, 1950.

This paper consists of a brief compilation of data on the fisheries of Pakistan submitted to the Government of Pakistan under cover of a letter of transmission conveying recommendations for Governmental action in respect of the fisheries. Tables are given of production, manpower, equipment and descriptions of types of gear and craft.

LEMASSON, J. L.: "Fishing Gear and Methods used in Continental Waters of South Vietnam"

Published by the Fisheries Research Institute, Phnom-Penh, Indo-China.

Sixty-eight different types of gear are enumerated and described. There is a great variety of harpoons, lines, trawl-lines and bow-nets, but the net-pouches, nets and various traps are the most important in respect of yield. It is shown that the fishing gear and methods of these waters are well adapted to the prevailing conditions, and that the gear in commercial use is more important than the gear employed in familial fishing.

"Note on French Trawling in Indo-China"

Published in Bulletin Economique de l'Indochine 53rd year, Nos V-VI, NS, Fasc. 44, May-June 1950.

The Oceanographical Institute of Indo-China has devoted part of its activities to a study of trawling possibilities. This report makes use of reports of the Director of the Institute, Mr. Krempiff and M. Chevey and of the Captain of the vessel "De Lanessan", M. Manquet.

A description is given of the equipment available for this work. This includes the vessel "De Lanessan", a fish-drying machine, a steam centrifuge, an array of machines for production of Nuoc-mam, a refrigerator for study of temperature effects on fish, and other equipment. The personnel is listed.

A brief account is given of the fishing grounds tested by the vessels. These include the fishing bank off Cape Khiao and off the Island of Bien-son; the bank of Bassac-Mekong at Cape St. Jacques on the continental shelf of Cochinchina, and the great bank by Ha-Tien and the islands in the Gulf of Siam.

An interesting feature is the remarkable concentration of fish off the mouths of the Mekong and Bassac which makes these grounds comparable with fishing banks of the Northern Hemisphere. The fishing operations and results are briefly described. The conditions of operations were extremely variable.

Various commercial attempts are also described in the period 1925-43. These attempts failed for various reasons described.

The future possibilities are discussed and particular attention is paid to the technological implications of the results to date. The actual fishing results are tabulated and a chart is given.

PRANJOTO, R. M.: "Fishing Industries of Indonesia"

To be published by Division of Sea-fisheries, Government of Indonesia.

Statistics of pre-war sea-fish production in Indonesia are quoted and discussed in relation to current production; factors affecting current production are discussed. Description is given of representative types of fishing gear in use in Indonesia.

CHARPY, C.: "Types of Barrage for Industrial Fishing in Cambodia"

Published by Fisheries Research Institute, Phom-Penh, Indo-China.

Advantage is taken, commercially, of the movement of fish through the channels of Tonle Sap at the time of the falling water, to capture the fish by special traps involving the construction of complete barrages across the water course. A general account is given of such barrages and of the factors which affect their operation. A special study of selected traps is reported; the costs and efficiency of construction and operation were examined and the conclusion reached that improvements could be effected.

LEMASSON, J. L., & A. LASSALLE: "Boats used in Cambodia for Fishing in Continental Waters"

Published by Fisheries Research Institute, Phnom-Penh, Indo-china.

The boats used for fishing in the continental waters of Cambodia belong to two categories: one comprising boats of Cambodian origin built to begin with from a a hallowed out tree trunk; the other comprising boats of Vietnames or Chinese origin, formed of assembled planks suppo.ted by ribs. Description is given of the principal types.

All these boats are well adapted to conditions of environment and utilisation. Their mechanisatiion could be considered. But in the case of the Ghelcui used in net fishing on the Great Lake, it seems preferable to consider the propulsion of the fishing unit composed of three Ghe-cui rather than the mechanisation of each Ghe-cui.

FOOD TECHNOLOGY

LAFONT, R.: "Forms of Utilisation for Food of Fish Products in the Inland Waters of Cambodia"

Published by Fisheries Research Institute, Phnom-Penh, Indo-china.

Reference is made to the considerable food contribution from Cambodian fisheries and to the fact that although a great deal of the catch is consumed fresh much of it is salted and dried. The reasons for wishing to reduce the latter proportion, and increase the former, are given. The manufacture of "Prahoc" and fish-oil is mentioned and special notice is taken of Nuoc-mam production. The conditions for increased export of fish products from Cambodia are discussed.

WOOD, E. J. F.: "Fish Marketing"

Some general principles affecting the conduct and management of fish markets are enunciated.

SOCIO ECONOMIC

MARTIN, C. & H. E. WARFEL: "Outlook for Industrialisation of the Philippine Fisheries"

To be published in "Philippine Journal of Fisheries"

The history of Philippine commercial fishing operation is described and discussed. The problems of maintaining current production and of expanding production along certain lines are discussed with special reference to the technological aspects of handling and distribution.

NEVILLE, W. C.: "Statement on Japanese Fisheries"

An account was given of problems encountered by the fishing industry in the economic rehabilitation of Japan in the post-surrender period, the extent to which production and facilities had been restored to pre-war levels consistent with principles of sound fisheries management, and in the economical utilisation of materials such as nets, twine, rope and petroleum necessary for operational needs and which originated from imports and U.S. relief funds.

Features of the recovery since the end of hostilities in 1945 have included: maximising production to a level of the pre-war period within the so-called SCAP authorised fishing area and the restoration of the fishing fleet to a level approximate in numbers and tonnage to that of the pre-war period.

Different types of Japanese fishing operations were illustrated and mention was made to the need of proper fisheries conservation or management programmes, in an effort to correct or to prevent over-fishing in some areas.

Section III

SYMPOSIUM PAPERS

1. Hydrology of the Estuarine Environment - - - - - - - - - - - - - - - - - 157

2. Physiological Aspects of Adaptation to Estuarine Conditions - - - - - - - - - 168

3. Estuarine Problems in South East Asia - - - - - - - - - - - - - - - - - - 175

4. Application of the Principles of Fish Culture to Estuarine Conditions in Singapore - - - 180

5. Preliminary Observations upon the Release of Phosphate from Estuarine Mud - - - 184

1

HYDROLOGY OF THE ESTUARINE ENVIRONMENT

by

D. J. Rochford*

The estuarine hydrobiological environment has only recently attracted the attention of ecologists and comparative physiologists, and even then the work is largely of a descriptive and often *ad hoc* nature. In this respect the hydrological features of this environment have suffered most.

In England the work on the Tees estuary by Alexander, Southgate and Bassindale (1), **although developed as a result of pollution problems, represents nevertheless a considerable advance on papers dealing with the specialized regions of the estuarine system (5 & 6). The longitudinal variation in the chlorinity conditions in an estuarine system can be ascertained from their paper and some indication is given of hydrological zonation.

For America, a paper by Nash (4) gives the hydrological properties of the Patuxent River, draining into Chesapeake Bay. This work was repeated over a period of years so that averages and annual ranges of properties can be computed from the tables published in the paper.

In France, the work of Varlet and Menaché on the Moros estuary in Concarneau (2) has been guided by the results of the Tees estuary survey. The seasonal range of hydrological properties for the Moros estuary, together with consideration of mixing phenomenon, has been discussed.

The paper by Tully (3) discusses in detail the mixing of fresh and marine water masses in an estuary.

Fig. 1. Map showing the location of the estuarine systems sampled by C.S.I.R.O. Fisheries Division.

* Hydrologist, Fisheries Division, C.S.I.R.O., Australia.

** The numbers in brackets refer to literature list at end of the paper.

However, in none of these papers is any consideration given to productivity of estuarine systems, nor are the ecological implications of the distribution of hydrological properties in such systems discussed. The examination of these aspects of estuarine hydrology on a comparative basis has been engaging the attention of C.S.I.R.O., Fisheries Division since 1940. Since that date, periodic hydrological investigations of a number of Australian estuarine systems have been carried out (Fig. 1). Within each system. sampling has been extended into the freshwater components; more recently bottom sampling has also been included in all surveys. The first of a series of papers on Australian estuarine hydrology will shortly be published and will discuss in greater detail the subject matter of this symposium address. It is proposed, therefore, to limit this address to an illustration of some features of estuarine hydrology and of estuarine productivity by examination of a number of representative systems.

It is necessary at this juncture to stress the difference between an estuarine and a brackish water environment. Brackish water is generally understood to mean sea water diluted by freshwater, and need not necessarily be influenced by tidal movement; it forms variously brackish water lakes, lagoons and other similarly stable environments. By an estuarine environment we mean one that is not only subject to long-term alteration in chlorinity and other properties by seasonal variations in the amount of fresh water dilution, but is also persistently under the short-term influence of tidal movement. The use of chlorinity conflicts as a measure of this effect is postulated in this paper.

THE ESTUARINE ENVIRONMENT

Definition of terms

In this paper the following meaning will be assigned to certain terms (fig. 2):—

(a) Estuarine system.—That part of a marine inlet or river having free communication with the open sea, extending from the natural marine entrance to the limit of persistent fluviatile flow. The estuarine system embraces both estuary and river components.

(b) Conflict.—In most estuarine systems and especially in certain zones, a pronounced tidal-generated diurnal variation in hydrological properties occurs. This diurnal variation has been termed the conflict. The diurnal conflict in chlorinity is termed the chlorinity conflict and similarly for other hydrological properties.

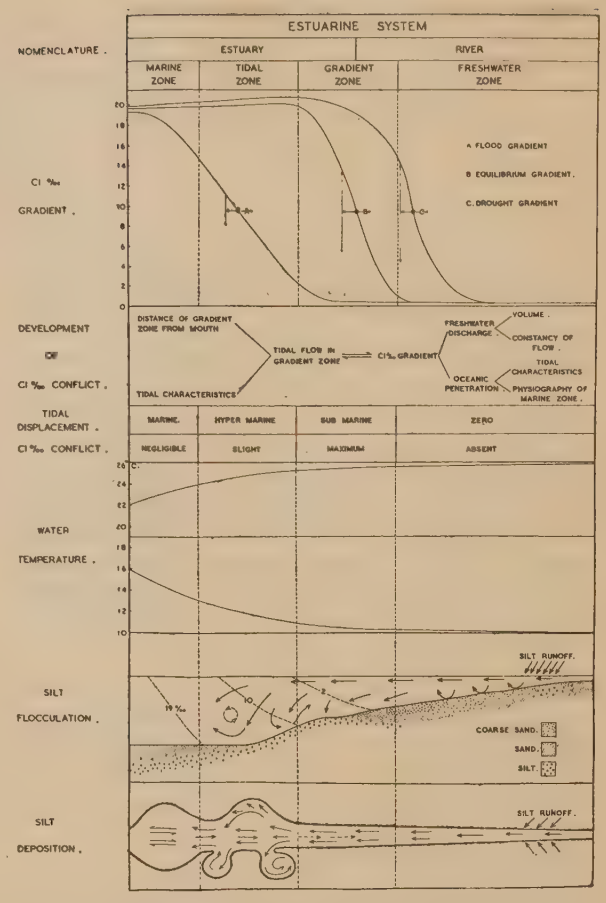


Fig. 2. Diagram showing some of the zonal features of a composite Australian estuarine system.

RAINFALL REGIMES OF AUSTRALIA AND THEIR EFFECT ON HYDROLOGICAL FEATURES OF ESTUARINE SYSTEMS

Fig. 3 in the upper left half depicts in inches the Australian January mean rainfall, and in the upper right the July mean rainfall. The lower half gives representative run off cycles for Australian coastal rivers. North of the Tropic of Capricorn the summer rainfall, as typified by the January distribution of isohyets, is at a maximum, whilst minimal to drought rainfall occurs during the winter months as typified by the July distribution of isohyets. In south-west Australia the converse applies, with winter maximum and summer minimum rainfall. In south-east Australia a more even seasonal distribution of rainfall is general, although reference to discharge data for the Clarence and Derwent Rivers plotted in the lower half of Fig. 3

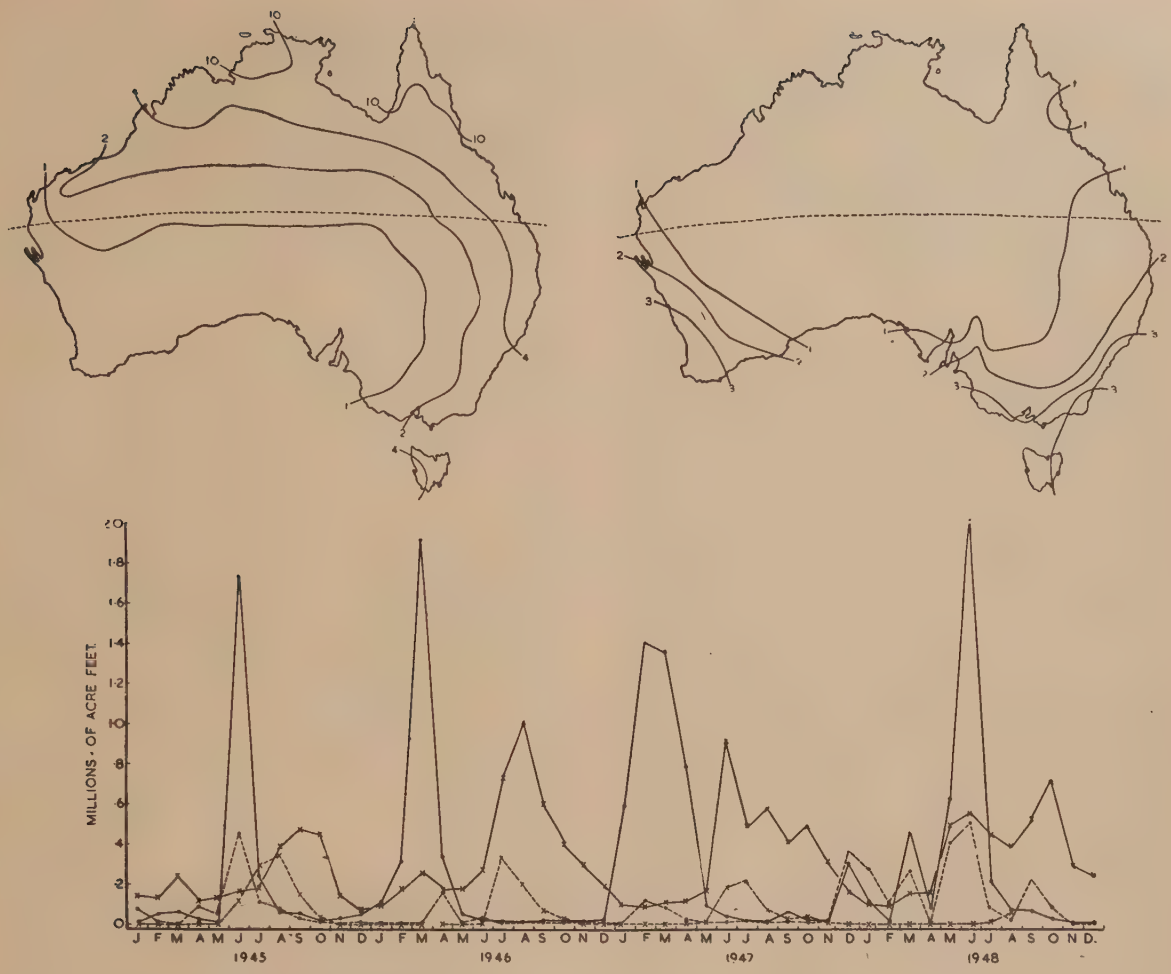


Fig. 3. Upper left: Average distribution of rainfall isohyets in summer.
Upper right: Average distribution of rainfall isohyets in winter.
Lower: Comparative discharge data for the following rivers.

o———————o Clarence R. N.S.W.
0 - - - - - 0 Nepean R. N.S.W.
x———————x Derwent R. Tasmania
X - - - - - X Blackwood R.W. Australia

Upper: Taken from Australian environment C S.I.R.O. Melbourne.

suggests a summer flooding cycle for the former and a winter flood cycle for the latter. The Derwent River is also affected by the melting of winter-spring snows on the central plateau, which often lead to a post-vernal and occasionally early summer secondary flooding of this system.

It is felt that the time of year during which flood scouring of an estuarine system occurs is of greater importance in its effect on estuarine productivity than the magnitude of such a scouring. In a system subject to winter-spring flooding, the maximum disruption of the plankton occurs at a time when, because of runoff nutrients and vernal stimulation, potential production should be at a maximum. In a summer flood system on the other hand, flooding occurs after the vernal plankton burst, during a period of nutrient exhaustion and plankton debilitation. Provided post-flood recovery of such a system is rapid, the increase in nutrients should stimulate late summer production.

The effect of flood discharges on the physico-chemical aspects of the estuarine environment is of course catastrophic. Up to a certain discharge level which is governed by the physiographic, tidal and hydrological features of each individual estuarine system, a dynamically balanced state is established, in which freshwater intrusion is absorbed by mixing with saline waters and subsequent seaward transfer by successive mixing exchanges (cf. Section 3). In summer, evaporation losses assist this process.

Each individual estuarine system is able to absorb a certain volume of freshwater without appreciable variation in the distribution of major hydrological properties. The volume of this equilibrium discharge varies with each individual system, and is dependent upon local physiographic, tidal and hydrological features. Above or below this equilibrium discharge, considerable displacement of water masses occurs and flood scouring or drought saline domination is the end result. The return of such systems to a normal state is also governed by local features.

In general, however, the normal hydrological state is developed fairly rapidly after flood scouring, except in the atidal south-west Australian systems (see Swan River, Section 9), in which penetration of marine water masses isostatically follows the recession of fresh-water volume without the accelerating processes of absorption by marine dilution and tidal transfer seaward of the diluted marine water mass.

It is so seldom that freshwater runoff ceases completely in south-east Australian estuaries that a reversion to a complete drought phase of distribution of hydrological properties is rare and need not be considered apart from the normal state.

In south-west Australia, however, where complete cessation of summer runoff occurs, penetration of saline water masses occurs to an extreme degree.

3. MIXING EXCHANGES AND CONFLICTS IN ESTUARINE HYDROLOGY

In an estuarine system there is a continual mixing exchange between freshwater and neritic water masses. The manner in which this mixing occurs determines to a large extent the zonal characteristics of the system. If vertical turbulence is a slight, mixing is largely confined to surface waters with small vertical exchanges and under such conditions a definite movement of surface water seawards and a counter movement of bottom neritic waters towards the upper reaches of the system, becomes established. This method of mixing exchange is common in the atidal systems of south-west Australia (see Fig. 4). If, on the other hand, vertical turbulence is high, mixing exchanges result in the formation of diluted water masses, each of which is to a certain extent isolated from adjoining water masses. Mixing, then, is largely a process of horizontal exchange across the vertical boundaries of these water masses (see Fig. 4).

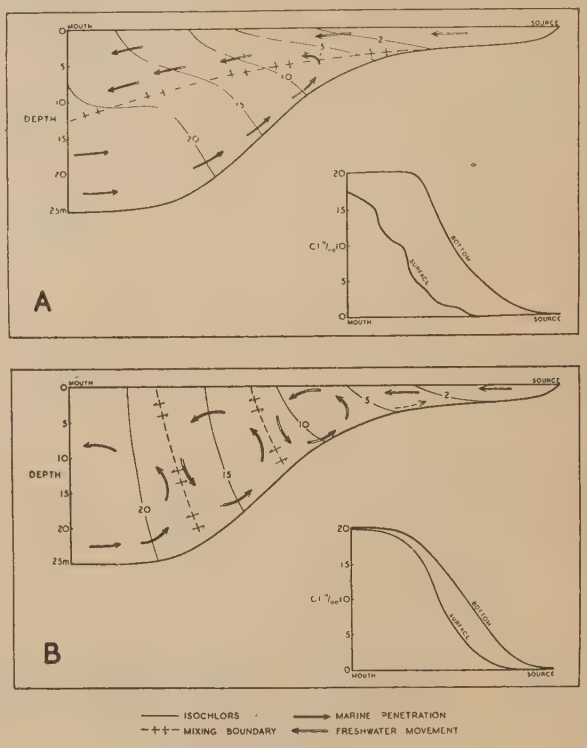


Fig. 4. A diagram showing the circulation paths and the type of mixing boundary developed in *A*. A typical atidal non conflict estuarine system and in *B*. A typical tidal estuarine system in which a conflict could develop. Both systems are assumed to be at a normal discharge level.

The small scale diagrams show the type of Cl‰ distribution to be expected in both types of systems.

Mixing, however, is a phenomenon which takes place to the greatest extent at the dimension of water particles, or even less. Superimposed upon the mixing exchange processes is the horizontal translatory movement of water masses developed as a result of tidal rise and fall of water level in an estuarine system. This translatory movement influences the mixing processes by its effect on the turbulence, but only incidentally, as the mixing processes occurring in the Swan River, in the absence

of tidal movement demonstrate. This translatory movement of water masses sets up a persistent diurnal cycle of variation in hydrological properties at any fixed reference point in the system, and it is possible, to guage the intensity of this translatory movement by measuring the diurnal variation in some convenient hydrological property. Since chlorinity is the most satisfactory water-mass identifying property in estuarine hydrology, the diurnal variation in chlorinity has been taken as a measure of translabory motion past a fixed reference point. This diurnal rhythm in chlorinity and other hydrological properties has wide ecological implications for fixed sessile organisms in an estuarine system. This diurnal rhythm, therefore, has been termed the conflict and the diurnal cycle in any particular property suitably prefixed, e.g. chlorinity conflict.

It has been found that the maximum chlorinity conflict within an estuarine system occurs in the gradient zone. Simultaneous determination of chlorinity conflicts at a number of stations in the George's River-Botany Bay estuarine system (see Table 1) clearly establishes this point. The enormous chlorinity conflict at Jerseyville on the Macleay River (see Table 1) is unaccompanied by a big rise and fall of water level, whilst at Deviot on the Tamar River a large rise and fall of water level is not associated with an almost imperceptible chlorinity conflict (see Table 1). Rise and fall of water level at a particular point in an estuarine system, therefore, may be a purely local phenomenon and not quantitatively indicative of translabory movement of water masses.

In an atidal estuarine system only minor mixing occurs vertically across horizontal boundaries and a marked difference in the surface and bottom diurnal cycles of hydrological properties occurs (see Table 1). Movement of surface water seawards, in such a system, is an isostatic phenomenon and takes place as successive energy thresholds are established. Such a threshold was apparently established at Fremantle Bridge at about 7 p.m. during the period of observation.

The factors considered operative in the development of conflicts are depicted in Fig. 3. In all mixing processes the effect of wind stirring must be considered as well as thermal overturning. Since wind and thermal effects are seasonal and vary enormously in efficiency, from one estuarine system to another, they have been neglected as factors in this diagram.

4. ZONATION IN AN ESTUARINE SYSTEM

A zonal diagram representing a hypothetical estuarine system is depicted in Fig. 2 which combines features from a number of systems. This system is assumed to be at a normal discharge level of freshwater (c.f. Section 2). Such a system consists of four hydrological zones:

Marine Zone. This zone consists of water masses which resemble in their hydrological properties the adjoining neritic waters. There is the same secular trend of nutrients, stability of the saline environment and magnitude of the annual temperature range. There is an almost complete absence of a chlorinity conflict. The bottom deposits are largely sand with (fig. 5) black muds at sub-surface depths. The depth of water is generally considerable, and there is a marked absence of the mud tidal flat and bays characteristic of regions further up the system.

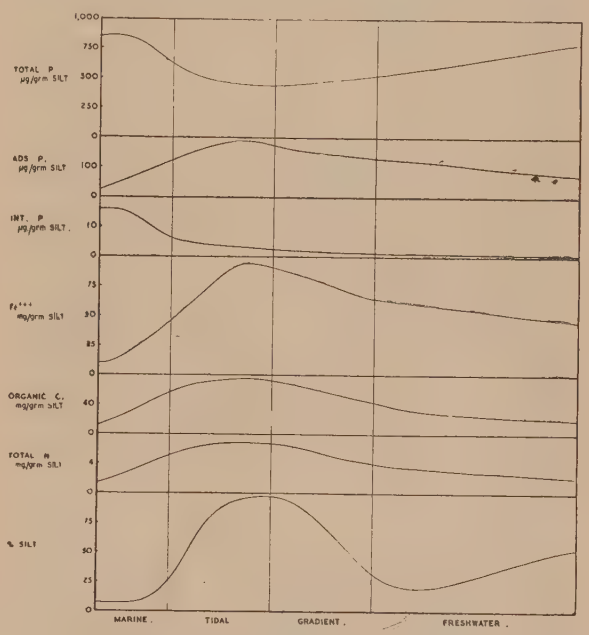


Fig. 5. The simultaneous diurnal variation in surface chlorinity, tide and water temperature at the following localities in George's River-Botany Bay. 17/viii/1945:

o————o Port Hacking. Hungry Point
x - - - - - x Kurnell
- - - - - - Shell Point
0————0 Picnic Point
-.-.-.-.- Hollywood
o.-.-.-.-.-. Prospect Creek
———— Ingleburn

The nutrient content of the bottom deposits is low and the greater part of the total organic productivity seems to occur in the water rather than in the bottom substrata.

Tidal Zone. This zone extends from the upper boundary of the marine to the lower boundary of the adjoining gradient zone. Although a fairly regular productivity cycle can be detected in the waters of this zone, its magnitude is considerably below that of the marine zone. Nutrient condition, turbulence and turbidity of the rather shallow waters of this zone probably account for this difference. The annual temperature range is much greater than that of the marine zone, whilst chlorinity conditions are stabilized at a higher level. A chlorinity conflict is generally absent.

The bottom deposits are largely composed of black flocculent mud, containing rich amounts of nutrients and especially phosphates. The large proportion of tidal exposed flats and bays in this zone gives it a characteristic appearance, and the important role of tidal condition in the establishment of its special features has prompted the term tidal zone (fig. 5). The productivity of this zone is concentrated on the surface of the mud flats, from which region plankton seeding of the overlying waters seems to occur. Productivity on the mud surface is largely a microbiological phenomenon involving bacteria, micro-flagellates and protozoa as well as some forms of sessile diatoms.

Gradient Zone. This zone represents the transition between the almost marine conditions in the tidal to the freshwater conditions in the freshwater zones. Within this zone the maximum variations in environmental conditions occur in respect of seaward displacement by freshwater pressure, and diurnal oscillation brought about by tidal forces.

Into this zone are swept freshwater organisms, and into it migrate also euryhaline organisms as suitable environmental conditions develop. On the whole, however, it is lacking in a stable plankton community and its annual productivity turnover is slight and irregular.

The bottom deposits consist mainly of grey-black muds, in the sheltered arms and the deltas at the mouths of the small creeks debouching into the main river. These muds are high in phosphatic nutrients but their low organic content suggests little biological utilization of these inorganic nutrient supplies.

The chlorinity conflict, as mentioned before, is at a maximum in this zone and, it is felt, plays a major part in the destruction of planktonic organisms in this zone, as well as limiting the upper penetration of ciliary feeding sessile organisms, such as the Sydney rock oyster, *Ostrea commercialis*.

Freshwater Zone. As its name implies this zone extends from the upper boundary of the gradient zone to the limits of persistent river flow. This zone is characterized by a stable environment, although subject to large annual variations in temperature and to the scouring effect of freshwater discharge. It contains a fairly specialized freshwater plankton community and does not appear to have a plankton cycle of productivity such as is encountered in its marine counterpart, the marine zone.

The nutrient content of the water is high in nitrates but often low in phosphates. The bottom deposits are composed largely of coarse sand, small pebbles and even boulders, with little or no silt muds. The nutrient content of these bottom deposits is low.

THE SILT DEPOSITION CYCLE IN RELATION TO ZONATION

During the runoff cycle from the hinterland considerable quantities of fine silt and colloidal clay particles carrying adsorbed nutrients, and particularly phosphates, on their surface are generally carried down into the lower zones of an estuarine system. As soon as the salt content of such silted waters is increased by mixing with marine waters, electrolytic flocculation of such particles occurs. The particles then begin to sediment out of the water mass. The rate of fall of such particles is dependent upon the viscosity of the water, size of the particles and especially the turbulence of the water. The turbulence of the water is at a minimum in the shallow bays and inlets of the tidal and gradient zones where maximum silt deposition occurs. The accumulation of black silted muds in the gradient-tidal zones can therefore be largely accounted for by electrolytic flocculation and sedimentation. A diagrammatic representation of these cycles is given in the lower half of fig. 2.

An analysis of the silt load of central New South Wales estuarine waters during flood conditions demonstrates that few nutrients and especially phosphates are being transported into them by present silted waters. The high phosphates content of the muds in certain zones of these systems must presumably, therefore, have been accumulated during the early stages of the estuary's existence in its present form, or have been introduced by relatively tremendous organic turnover in the overlying waters during successive marine submergence cycles.

PORT HACKING AS AN EXAMPLE OF A MARINE-DOMINATED ESTUARINE SYSTEM

Fig. 6 gives the location of the sampling stations referred to in this section.

Port Hacking is a drowned valley system with a wide and shallow marine entrance but poorly deve-

Fig. 6. Map. showing the location of the sampling stations in the Pt Hacking system.

loped fluviatile components interrupted by a weir at station 8. In the middle of the system basins scoured down to a depth of about 100 feet are found, but the average depth is much less, probably not greater than 20 feet. This system has a volume of 77 x 10^6 c. metres.

In general, flood scouring of the system is a rarity and rainfall incidence is spread over the year.

Table 2 gives the annual means of chlorinity and temperature for all stations in this system during 1947 in the surface and bottom waters respectively. Between stations 1 and 4 in the surface and for all stations in the bottom waters, the chlorinity stability is evident. From station 4 onward greater variability in the surface waters is evident but no evidence of flood scouring or persistent freshwater influence is to be seen.

Annual means and range of temperature are practically constant throughout the system.

Nutrient conditions in suface and bottom waters respectively during the same year are given in Table 2. In subsequent discussions on productivity attention will be focussed on the phosphate cycle. It is felt that as nitrate nitrogen is only one of several sources of nitrogen available to the phytoplankton and moreover, as Harvey's laboratory experiments have shown, is less preferred to ammonium nitrogen by plankton cultures, its usefulnes as an index of productivity is much less than that of phosphate phosphorus.

In the surface waters the organic phosphates are consistently higher than the inorganic phosphates with little zonal differentiation. In the bottom waters the amounts of inorganic and organic phosphates are greater than for the surface waters but equal in magnitude. There is also a considerable reduction in the average oxygen content of the deep compared with the surface waters of this system.

A consideration of the seasonal cycles of properties at station 4 Port Hacking during 1946-48 (Table 3 (1).) gives an explanation of this differentiation. The low oxygen content of the bottom waters is brought about by de-oxygenation cycles during the summer-autumn periods. Surface values during these periods appear to be above saturation. The de-oxygenation cycles appear to be closely linked with rather tremendous turnover of phosphates in the bottom waters. That this is an *in situ* turnover is fairly clearly shown by the alternation of organic and inorganic peaks. Although similar peaks can be discerned in surface waters the turnover is considerably reduced.

If we assume that *in situ* phosphate turnover is governed by plankton activity, then rather continuous plankton turnover appears to be general in Port Hacking waters from early summer to late autumn.

Throughout this system the bottom deposits contain considerable quantities of total phosphates. A maximum of adsorbed phosphates towards the freshwater end of the system (Table 2) is correlated with a similar maximum of organic carbon and total nitrogen (Table 2). In a marine dominated system and in the marine zone of most systems investigated this seasonal turnover of phosphates is typical.

Plankton production of the neritic type appears to be a feature of this zone. Detrital contribution to the bottom deposits appears to be the chief factor responsible for the high total phosphate carbon-nitrogen content of the deposits in a marine dominated system.

No data are available as yet for assessing the rate of transfer of nutrients from the bottom deposits to the overlying water but the sandy nature of such deposits renders it likely that such exchanges do take place fairly readily.

HAWKESBURY RIVER AS AN EXAMPLE OF A GRADIENT-DOMINATED SYSTEM

The Hawkesbury River system is of considerable magnitude (fig. 7). It is navigable up to 75 miles from the mouth and has very extensive fluviatile components draining an area of some 1,800 sq. miles. Around the mouth and especially in the big inlets off the lower reaches depths of water down to 60 feet are common. The volume of the system to the head of navigation at station 21 is 750 x 10^6 c. metres.

Although severe flooding can occur in this system because of its extensive drainage area, the system appears to be able to absorb by dilution without appreciable zonation displacement, all but

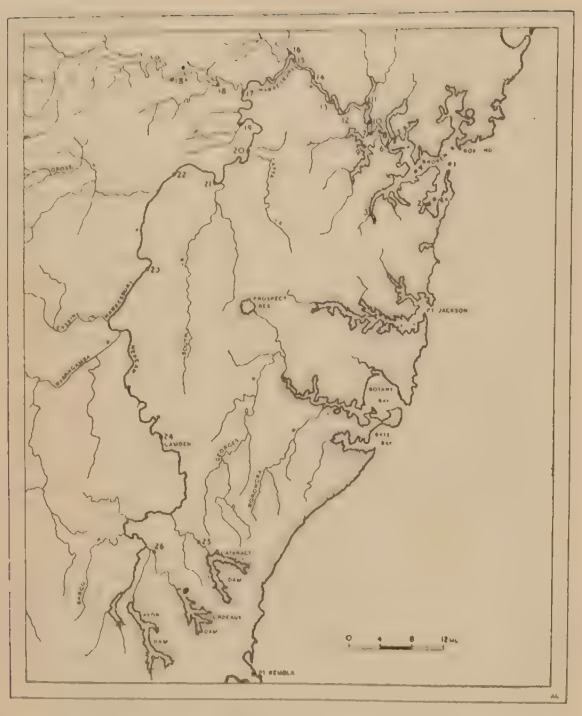


Fig. 7. Map showing the location of the sampling stations in the Hawkesbury River system.

major flood discharges. Even then there is very seldom a disruption of the zonation but only a seaward displacement with post-flood recovery very rapid.

Table 4 gives the mean distribution of surface and bottom chlorinity and temperature in this system during 1946.

The absence of any marine or tidal zone except perhaps during the summer period is indicated by the chlorinity distribution. The dominance of the system by a gradient zone extending from near the mouth to some 50 miles upstream is also quite clear.

The correspondence between mean curves for surface and bottom waters is indicative of the strength of vertical mixing in this system. The divergence of the annual temperature range, proceeding upstream, and the stability of the mean are characteristic of most estuarine systems. The nutrient conditions for 1946 also are given in Table 4.

In the surface and bottom waters there is a persistent decrease in the average content of inorganic phosphates to be correlated with the phosphate lack of the hinterland soils of this system. An increase in the organic phosphate figure is probably an effect of insoluble silt-borne inorganic, rather than organic phosphate.

A gradual decline in the surface oxygen content to a minimum in the mid-gradient zone is probably an effect of persistent oxygen demand by plankton decomposition in this zone. In the bottom waters extensive de-oxygenation, such as occurs in the Port Hacking system, is absent.

The high average content of nitrate nitrogen in this system is an effect of persistent freshwater inflow.

At station 1 (Table 3(2)), the oxygen content has never fallen below a figure of about 8% saturation in the period 1946-48. During the same period (Table 3(2)) the phosphate turnover is much less than for the Port Hacking system, but it is clear that it is an *in situ* phenomenon and moreover, appears to be equally well developed in surface as well as bottom waters.

The total phosphate content of the bottom deposits of this system (Table 4) is not very high except in the upper freshwater zone. In the silted lower portion of the gradient zone, the adsorbed phosphate content reaches a maximum of about the same concentration as in Port Hacking.

The carbon and nitrogen content (Table 4) of the bottom deposits varies with the total phosphates, but is comparatively low especially in the marine end of the system.

It appears, therefore, that in an estuarine system subject to gradient zone domination environmental characteristics and in particular turbulence and nutrient poverty prevent plankton production of the marine type, and moreover, hinder the potential production of the microbiota of the bottom deposits of the type that occurs in a system such as George's River-Botany Bay (fig. 28), where productivity of the mud enables extensive oyster cultivation to be practised in the tidal zone.

RICHMOND RIVER AS AN EXAMPLE OF A SUMMER FLOOD FRESHWATER-DOMINATED SYSTEM

The Richmond River (fig. 8) is a broad but relatively shallow river, navigable for some 10-20 miles from the mouth. The river is some 120 miles in length. No extensive development of sheltered and muddy-bottomed inlets and bays is found except in the immediate vicinity of the mouth.

The chlorinity-temperature conditions in this system are given in Table 5. The distribution in Table 5(1) was encountered immediately after a severe flood discharge. It is apparent that the recovery rate of this system to a normal distribution shown in Table 5(3) is rapid and that the latter distribution is normal for the greater part of the year

Fig. 8. Map showing the location of the sampling stations in the Richmond River system.

The steepness of the chlorinity gradient combined with the length of the freshwater zone shows the extent of freshwater domination.

The nutrient runoff, and particularly phosphates, is very high in this system (Table 5(3)). Even during minimal discharge, a considerable quantity of inorganic phosphates is still present (Table 5(1)). This phosphate richness is to be attributed to the exceptionally high phosphate content of the hinterland soils in this area. The low organic phosphate content and the sub-saturation oxygen values suggest that little planktonic utilization of these nutrients occurs during normal discharge.

The phosphate richness of the waters of this system is reflected in the high adsorbed phosphate content of the bottom deposits (Table 5(2)). These adsorbed phosphates are associated with the silted bottom deposits of the lower freshwater zone. The organic carbon and nitrogen content of these muds is, however, very low and is probably due to lack of micro-biological fixation consequent upon the severity of annual flooding and the freshwater domination of the potentially productive muds.

In this freshwater dominated system, although large quantities of phosphatic nutrients are persistently available, the obliteration of the marine and tidal zones does not permit of the establishment of a plankton community of the type found in Port Hacking. The steepness and therefore sensitivity of the gradient zone to variations in the tremendous volume of freshwater above it, precludes the establishment of a smaller specialized plankton community of the type found in the gradient zone of the Hawkesbury River. The persistent annual scouring and the freshwater domination prevents the establishment of a semi-marine micro-plankton community of the type associated with the mud flats in the tidal zone of the George's River.

A freshwater dominated system, therefore, is unable to utilize to anything like maximum capacity the continous supply of inorganic nutrients contributed by runoff. It is considered, therefore, to possess a high potential but low actual plankton productivity. This is reflected in the low organic phosphate content of the water and the low carbon nitrogen content of the bottom deposits.

SWAN RIVER AS AN EXAMPLE OF AN ATIDAL ESTUARINE SYSTEM

The Swan River system (fig. 9) has a total length of about 40 miles to station 14 and another 60 miles to the headwaters of the Avon River tributary. In the lower portion a deep basin with depths of 40-60 feet extends from about station 6 to 4. The remainder of the system is predominantly shallow, with depths of less than 10 feet. The drainage area of the Avon and Canning Rivers is about 1,500 sq. miles.

Fig. 9. Map showing the location of the sampling stations in the Swan River system.

The data of Table 6 display certain characteristics in the distribution of chlorinity and temperature which are developed as a result of the lack of tidal mixing. In the surface water the stepped nature of the mean curve and its convexity towards the mouth of the system are effects of freshwater pene-

tration solely under the influence of an isostatic head in the Canning and Avon Rivers. The extreme variation from the summer drought to winter flood conditions and the penetration of saline conditions to the upper Swan Stations are effects of the almost complete summer cessation of river flow and the concentrated discharge in late winter-early spring.

The relative isolation of the bottom waters occupying the basin between stations 3 and 5 can be seen from the distribution of chlorinity and temperature in Table 6. There is a considerable discharge of phosphates into this system, as can be seen by reference to Table 6. The persistent decline in the surface oxygen tension proceeding upstream, and the de-oxygenation of the bottom waters of the basin in the lower reaches are of importance in the assessment of productivity.

The seasonal alternation from winter flood to summer drought environmental conditions is given in Table 3(3). The relative stability of the bottom waters is to be noted. The corresponding cycle of nutrients, Table 3(3) shows clearly that in spite of freshwater influx of nutrients, little local fixation and turnover occur in the environmentally stable summer period.

In the bottom deposits of this system there is a marked peak of adsorbed phosphates at station 9 (Table 6) which is probably associated with a similar peak in phosphates of the overlying water at this point. The persistent decline in total phosphates is paralleled by a similar trend in total nitrogen and to a less extend by organic carbon.

It is considered likely that in view of the environmental instability of the surface waters and their nutrient summer depletion, such productivity as occurs in the Swan River system is mainly confined to the bottom waters and especially bottom deposits. Insufficient data are available for comparison with bottom productivity of eastern Australian systems but it is probable that the high nitrogen and organic carbon content of the Swan River muds is bound up with considerable biological activity.

TROPHIC DIAGRAM FOR ESTUARINE SYSTEMS

From a consideration of the estuarine data collected by C.S.I.R.O. Division of Fisheries, the following flow diagram of factors responsible for the determination of its trophic level in an estuarine system has been constructed (fig. 10). A good deal of simplification has necessarily to be practised in the construction of such a diagram but the following groupings can be followed:—

Nutrient content of bottom deposits.—The rainfall regime acting upon the hinterland soils to a large extent determines the quantity and nutrient quality of the bottom deposits. The disposition of such deposits is a function of local tidal and physiographical features. The micro-biological activity in the environmentally suitable regions of such deposits contributes to the productivity of certain systems, and in some cases, it is felt, provides a nursery ground for micro-planktonic organisms of the overlying water mass.

Nutrient content of water masses.—The nitrogen and phosphatic compounds, together with trace elements and possibly soil enzyme systems, are a direct contribution of runoff. The successful fixation and retention of such elements in the estuarine system depends upon the quality and quantity of the plankton and benthic fauna and flora. The quantity and quality of plankton organisms especially are dependent upon the persistence of a suitable environment, both in respect of zonal buffering and short-term conflicts.

There appears to be a linkage between plankton production in the water mass and the fixation of detrital matter in the corresponding bottom deposit.

11. PLANKTON IN RELATION TO THE HYDROLOGICAL ZONES

The volume of the rainfall, together with the bathymetric and tidal characteristics of the system, determine the relative development of each of the four hydrological zones.

Productivity of an estuarine system is largely determined by the relative environmental stability of these zones. The marine zone has maximum stability and productivity therein follows the neritic plankton cycle. The tidal zone, because of its shallow depths, turbulence and turbidity, does not favour neritic plankton production. Productivity therein is largely governed by microbiological activity on the surface of the nutrient-rich mud substrate. In the gradient zone, establishment of a specialised plankton population is possible in some systems, e g. Hawkesbury River, but not in others, e.g. Richmond River. In the freshwater zone, establishment of a specialized biological population able to withstand the effects of persistent flow and rocky substrate occurs.

12. BIBLIOGRAPHY

ALEXANDER, W. B., B. A. Southgate, & R. Bassindale, (1935) .—Survey of the River Tees. Part II. The estuary—chemical and biological. Dept. Sci. Indust. Res. Water Pollution Research. Tech. Paper No. 5. H.M. Stationery Office, London.

VORLET, F., & M. L. Menache, (1947) .—L'estuarie du Moros a Concarneau (Finistere). Etude du melange des eaux

TABLE 1.

THE DIURNAL VARIATION IN SURFACE (S) AND BOTTOM (B) PROPERTIES

Hours †	0	2	4	6	8	10	12	14
			(1)** STATION: PICNIC POINT, GEORGE'S RIVER 6—7/10/					
(1)** Tide height inches	54"	54	36	17	7	22	38	43
Cl‰	17.2	17.5	17.0	14.8	8.8	13.2	15.2	17.0
Water Temp. °C	17.5	17.8	18.0	18.2	18.5	18.5	18.0	18.0
NO_3N	20		22		160		50	
Inorganic PO_4P	3		2		1.2		3	
Saturation $\%O_2$	87	91	87	92	81	82	71	88
			(2)** STATION: JERSEYVILLE, MACLEAY RIVER 27—28/1					
(2)** Tide height inches	43"	28	18	22	39	40	27	12
Cl‰	18.4	13.2	6.0	5.0	5.2	8.6	8.8	5.2
Water Temp. °C	23.2	24.4	24.4	24.4	24.4	24.2	24.2	24.2
NO_3N	0		0		60		31	
Inorganic PO_4P	14		30		25		36	
Saturation $\%O_2$	96	90	76	75	76	80	80	77
			(3)* STATION: DEVIOT, TAMAR RIVER 5—6/3/1948					
(3)* Tide height inches	10	53	85	66	45	11	5	50
Cl‰	16.8	16.8	17.0	17.1	17.1	16.9	16.8	16.9
Water Temp. °C	18.1	17.7	16.8	16.9	16.6	17.1	16.3	16.3
NO_3N	7		5		32		20	
Inorganic PO_4P	10	8	11	9	14	13	14	9
Organic P.	6.5	—	6.0	6.0	5.0	2.5	2.0	6.5
Saturation $\%O_2$	91	93	90	90	—	—	88	88
			(4)* STATION: FREMANTLE RAILWAY BRIDGE 23—24					
(4)* Tide height inches	45"	44	43	42	40	35	38	43
Cl‰ Surface	14.5	6.0	11.5	7.5	6.0	3.9	3.4	2.5
Cl‰ Bottom	19.0	19.5	19.0	19.5	19.5	19.0	19.5	19.5
Water Temp. °C Surface	15.9	16.2	16.2	16.0	15.7	14.2	14.1	14.0
Water Temp. °C Bottom	16.9	16.8	16.8	16.8	16.8	16.7	16.6	16.7
NO_3N Surface	120	290	160	290	292	320	290	290
NO_3N Bottom	5	1	5	4	4	4	2	1
Inorganic PO_4P Surface	8.5	22.0	12.0	19.6	12.0	22.0	19.6	15.0
Inorganic PO_4P Bottom	7.0	7.0	7.0	6.0	0	7.0	4.0	1.0
Saturation $\%O_2$ Surface	88	87	85	89	91	91	88	88
Saturation $\%O_2$ Bottom	86	93	93	88	94	94	89	91

† Hours from commencement of series

NOTE: The data in these tables were extracted by the Editorial Committee from text figures submitte necessity of this method of presentation, some smoothing of and variation from the original ra

AT VARIOUS STATIONS.

16	18	20	22	24
1948, Commencing at 11 a.m.				
37	11	15	30	48
15.2	14.0	12.6	14.2	16.8
17.8	17.8	17.8	17.8	18.0
55		165		50
3		2.2		3
62	83	81	82	87
/1948, Commencing at 1 p.m.				
8	32	50	58	48
2.7	3.2	—	18.2	19.0
24.2	24.2	24.0	23.0	23.0
2		2		2
27		26		15
70	72	—	103	105
, Commencing at 4 p.m.				
100	77	42	6	0
17.1	17.1	17.2	16.7	17.0
17.0	18.0	19.1	19.5	18.0
1		1		10
10	11	19	16	6
2.5	2.0	0	14.0	13.0
90	95	94	94	95
/7/47, Commencing at 9 a.m.				
42	43	44	43	43
2.2	3.7	4.0	4.3	5
19.5	19.5	19.0	17.5	17.5
14.0	14.0	13.9	14.0	13.9
16.7	16.7	16.8	16.2	16.2
290	290	295	270	295
1	1	1	40	30
27.0	14.0	16.5	16.0	15.0
7.5	6.0	5.0	7.0	6.5
88	89	90	93	92
91	93	93	96	95

d by the author and, due to the unfortunate
w data has been inevitable.

TABLE 2.

PORT HACKING.

Station Number	1	2	3	4	6	7	8
Distance, miles*	0	1.5	2.5	3.5	5.0	6.0	8.5

(1) PT. HACKING MAY, 1947.

LONGITUDINAL DISTRIBUTION OF SUBSTANCES IN THE BOTTOM DEPOSIT.

Organic C. mgm/gm Silt.	36	18	27	41	42	74
Total N. " " "	3.0	1.7	2.3	3.2	2.5	4.3
Absorbed P. ugm/gm. "	9	1	15	62	31	74
Total P. " " "	460	430	515	530	390	680
Interstitial P. ugm/gm mud.	6	7	15	1	1	1
Silt %	10	5	5	7	3	29
Fe $^{+++}$ Iron mg/gm Silt.	12	35	5	12	10	15

*Distance is miles from mouth of system.

(2) PT. HACKING 1947.

MAXIMUM MEAN, MINIMUM VALUES OF CERTAIN PROPERTIES OBSERVED DURING THE YEAR AT VARIOUS STATIONS.

Cl‰	Max.	S	19.8	19.9	20.0	19.8
		D	19.8	19.9	20.0	19.8
	Mean.	S	19.4	19.2	18.8	14.8
		D	19.4	19.5	19.6	18.2
	Min.	S	17.2	17.7	11.3	2.3
		D	19.2	18.7	19.2	15.7
Water Temp.	Max.	S	26.0	26.1	25.2	27.0
		D	23.1	26.8	24.1	27.2
	Mean.	S	19.2	19.2	19.1	20.0
		D	18.4	18.3	18.4	20.0
	Min.	S	12.0	12.8	13.2	14.2
		D	12.2	13.3	13.0	13.4
NO_2N	Max.	S	65	15	20	125
		D	40	80	36	98
	Mean.	S	19	14	15	28
		D	19	19	17	19
	Min.	S	4	0	0	0
		D	5	0	0	0
Inorganic PO_4P	Max.	S	8.5	8.5	20.0	7.0
		D	17.5	35.0	25.0	36.0
	Mean.	S	2.6	2.6	3.4	2.0
		D	6	7	6	5
	Min.	S	0.5	0.5	0.5	0.5
		D	0.4	0.4	0.4	0.4
Organic $P.O_4D$	Max.	S	14	16	22	16
		D	43	24	22	24
	Mean.	S	5	6	6	7
		D	8	7	6	6
	Min.	S	0.2	0.2	0.2	0.2
		D	0.6	0.6	0.4	0.4
$\%O_2$ Saturation	Max.	S	106	110	108	112
		D	111	99	100	99
	Mean.	S	99	95	97	90
		D	100	76	77	78
	Min.	S	90	80	86	78
		D	90	32	39	17

TABLE

THE SEASONAL CYCLE OF PROPE

			1946														
			1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
(1) STATION NO																		
NO_3N		S	0	0	10	5	0	2	10	24	0	0	12	5	12	10	10	10
		B	10	11	15	3	24	5	12	25	2	3	13	13	13	93	13	11
$\%O_2$ Saturation		S	98	98	92	97	105	95	96	97	99	89	103	93	97	80	99	92
		B	59	92	85	70	93	70	94	92	93	90	84	16	89	49	59	87
Cl‰		S	19.5	19.6	19.5	18.0	18.0	17.8	19.0	19.4	19.8	18.7	19.2	18.0	19.9	19.8	19.7	19.7
		B	19.5	19.7	19.7	19.5	19.2	19.2	19.2	19.5	20.0	20.0	20.0	18.0	18.5	19.8	19.7	19.7
Water temp. °C		S	23.3	23.5	22.2	18.5	17.0	14.2	13.5	13.5	15.0	18.5	21.0	20.5	24.5	24.0	24.0	20.0
		B	21.1	22.3	21.5	18.0	17.0	15.2	13.6	12.5	13.7	16.0	19.1	18.5	24.5	22.8	23.4	19.0
PO_4P	Deep	Inorganic	5.0	8.8	3.0	6.0	16.0	1.9	0	0	4.2	5.0	0.9	0	0	19.2	7.0	3.0
		Organic	16.9	11.0	7.4	7.1	13.2	6.2	6.3	23.1	0	6.2	6.8	24.4	14.2	3.1	10.0	3.7
	Surface	Inorganic	3.5	1.2	0.8	1.9	1.9	2	0.1	0	1.2	1	0	0	0.7	6.7	0.1	1.0
		Organic	10.0	9.2	11.8	7.2	6.2	0	5	11.1	2.2	7	4	5	5.0	0	5	5.0
(2) STATION NO. 1																		
NO_3N		S	0	12	105	40	30	15		12	2	2	54		12		15	
		B	10	24	105	24	24	5		—	2	2	78		12		18	
$\%O_2$ Saturation		S	100	98	95	85	102	85		98	100	97	95		93		97	
		B	100	103	100	82	102	83		98	100	95	91		93		93	
Cl‰		S	19.6	19.5	19.4	19.2	19.1	18.5		19.1	19.1	19.2	19.3		19.2		19	
		B	19.8	19.6	19.5	19.4	19.4	19.4		19.4	19.4	19.4	19.1		19.4		19.2	
Water Temp. °C		S	22.3	22.3	21.5	19	17.8	16.5		14.8	15.4	15.5	19.4		21		20.5	
		B	21.4	23.2	21	19	17.8	17.8		14.8	15.4	16.8	18.6		20.8		19	
PO_4P	Bottom	Inorganic	0	4.8	1	5.5	3	1.1		0.3	1	5.5	5.5		0		1	
		Organic	7	2.1	8.8	3.5	1	0.4		0.3	0	4.2	4.2		8.4		12	
	Surface	Inorganic	0	3	0.5	6.9	0	—		1.2	1.2	4.2	3.2		0.2		0.2	
		Organic	9	1.2	7	3.2	6	1		—	0.2	2.2	8.6		7.2		6	
(3) STATION N																		
Cl‰		Surface.															19.4	
		Bottom.															19.4	
Water Temp. °C		Surface.															23.5	
		Bottom.															23.5	
NO_3N		Surface.															8	
		Bottom.															7	
Inorganic. PO_4P		Surface.															0	
		Bottom.															1.1	
$\%O_2$ Saturation.		Surface.															96	
		Bottom.															97	

3.

TIES AT VARIOUS STATIONS.

1947								1948										
5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
. 4 PORT HACKING.																			
13	12	8	5	5	2	0	12	15	8	2	12	0	20	2	1	1	1	1	1
16	36	14	8	9	7	8	26	10	12	2	20	8	12	2	1	1	1	1	1
97	89	98	100	101	92	100	100	95	91	96	91	97	96	102	104	100	97	92	99
33	68	97	96	88	90	87	32		80	79	83	64	72	96	97	92	89	90	63
19.4	18.0	19.6	19.7	19.8	19.8	19.9	14.0	18.3	19.0	19.5	19.5	18.5	15.5	19.0	19.5	19.5	19.8	19.9	19.8
19.5	19.4	19.7	17.8	19.9	19.9	20.0	19.7	19.6	19.5	19.6	19.6	19.6	19.5	19.2	19.5	19.9	19.7	19.8	19.7
1 19.0	17.2	14.0	13.5	14.5	16.2	18.5	23.4	22.5	23.5	23.0	21.4	18.0	14.3	13	14.5	16.0	18.5	18.3	21.7
18.8	17.5	13.4	13.5	14.0	16.5	18.5	20.0	19.5	21.7	21.6	20.6	16.5	15.5	12.8	14.0	14.7	17.8	17.0	19.5
1.0	6.0	1.0	7.8	6.0	10.0	3.0	36.0	69.0	11.0	19.0	6.7	11.0	11.0	0	1.8	6.7	8.0	11.0	14.0
5	11.1	1.9	0	0	0	18.0	5.0	1.9	8.5	10.0	3.0	10.0	8.0	15.5	8.5	8.0	10.0	4.3	26
0	0	0	9.0	5.0	5.0	3.0	3.0	6.0	3.8	11.0	4.9	3.0	4.0	0	7.2	4.2	6.0	10.0	6.0
3.0	6.7	3.0	0	4.0	8.9	9.0	9.0	6.0	12.0	5.0	9.0	21.0	6.0	—	1.9	7.5	7.8	0.1	22
HAWKESBURY RIVER.																			
30	18	20	5	0	13	5	240	0	10	2	0	6	35	2		2		5	
78	45	28	30	0	58	5	2	0	62	10	0	6	35	2		2		5	
92	99	95	102	105	93	110	94	103	108	93	96	99	100	104		93			
77	94	91	97	100	87	107	85	105	100	95	98	93	100	99		94			
19.1	18.8	19.1	19.5	19.5	19.5	19.5	4	17	17.2	18.3	19.5	19.2	19.2	19.2		19.2		19.3	
19.4	19.5	19.6	19.6	19.2	19.5	19.6	19.2	19.2	19.3	19.2	19.5	19.6	19.6	19.6		19.6		19.4	
19	16	15.5	16.1	16	17.5	18.2	19.6	22.8	22.3	20	19	17.2	16	15.5		16.6		18	
18	17.5	16.8	16.1	15.7	15.5	18	18.3	22.2	22	20.5	19	17.7	16.7	15.5		16.5		18	
10	0.8	3.0	5.0	8.5	12.5	6	5.3	2	0.2	10	5.4	2	7.6	5		6		6.8	
—	2.2	2.2	9.8	3	9.4	1.2	15	14	20	2	5.4	9	4.8	6		7		—	
3.0	0.1	0.1	4.2	10.0	9.0	7.2	8.4	4	9	0.2	6	16	13.5	4		6		6.8	
—	4.5	1	5	2.4	7.0	4.2	13.2	6	1.2	12	8.2	0.1	0.1	9		6		—	
D. 3 SWAN RIVER.																			
10	18.4	6.7	0.8	15.2	6.1	8.4	14			18.7		19.6	19.2	18	4.4	5.1			
10	18.5	18	15.2	16.8	11.2	18	15.3			18.9		19.6	19.2	18.8	18	16.7			
10.2	18	17.4	14.1	15.4	17.2	18	22.2			24		19.8	19.2	15.3	15.9	20.8			
10.2	19	18.5	16.2	15.4	16.8	17.2	20.5			24		19.8	19.2	16.3	16.3	19.2			
6	26	135	250	55	13	31	19			12		4	32	84		230			
0	26	19	94	65	13	22	13			6		4	29	74		13			
2	0	2	20	3	11	4.5	2			0		3	0	8		17			
2	0	2	5.5	5.5	14	5.5	2			0		1	0	11		0			
d 10	88	78	86	92	98	92	98			98		95	93	91		98			
w 0	89	84	90	80	98	84	95			95		95	95	93		97			

TABLE

HAWKESBURY

Station Number	1	3	4	5	6	7	8	9	10	11	12
Distance	0		4.5		9.5		13.5		17.5	21.5	26.

1. HA

LONGITUDINAL DISTRIBU

Organic C. mg/gm Silt	17	21	9	16	17	19	18	21	21	20
Total N. mg/gm Silt	3.7	2	1.1	1.1	1.5	1.4	1	2.4	1.5	1.5
Silt %	4	6	4	84	89	61	58	96	48	72
Fe^{+++} Iron mgm/gm Silt	6	20	14	18	20	11.2	9	9.2	17	18
Total P. ugm/gm Silt	100	712	200	317	390	361	280	300	330	280
Adsorbed P. ugm/gm Silt	1	47	0	35	48	37	30	27	24	30
Interstitial P. ugm/gm Silt ugm/gm Mud	10	0	0	0	0	0	0	0	0	0

2. HAWKESBUR

1. MAXIMUM, MEAN AND MINIMUM VALUES OF CE

Cl‰	Max.	S	19.6	19.3	19.1	18.8	18.6	18.2	16.
		D	19.6	19.6	19.4	19.0	18.8	18.4	17
	Mean.	S	19.3	19.0	18.5	17.2	16.3	15	12.
		D	19.5	19.2	18.6	17.6	16.8	15.8	13.
	Min.	S	18.6	17.3	16.1	13.2	11.0	8.2	6.
		D	19.4	18.3	16.6	14.0	12.8	11.2	8.
Water Temp °C	Max.	S	22.7	25.8	25.0	26.2	26.8	26.8	26.
		D	23.8	24.8	26.4	26.8	27.3	27.0	27.
	Mean.	S	18.7	19.0	19.2	19.4	19.5	19.6	19.
		D	18.8	18.8	19.5	19.4	19.4	19.4	19.
	Min.	S	14.6	14.2	14.6	13.5	13.5	13.5	13.
		D	14.4	14.2	13.9	13.8	13.7	13.5	13.
NO_3N	Max.	S	110	75	160	200	290	560	510
		D	105	80	110	210	290	310	410
	Mean.	S	30	40	50	55	70	130	160
		D	30	40	45	60	70	100	160
	Min.	S	2	2	2	3	20	15	10
		D	1	2	2	3	10	5	3
Organic P.	Max.	S	9	—	14	—	—	8	—
		D	9	—	66	—	—	7	—
	Mean.	S	4	—	4	—	—	3	—
		D	4	—	10	—	—	3	—
	Min.	S	0	—	0	—	—	0	—
		D	1	—	0	—	—	0	—
Inorganic PO_4P	Max.	S	7	7	8	9	5	5	5
		D	6	8.5	8	8.5	6	7.5	7
	Mean.	S	3	4	4	4	3	3	3
		D	3	2	3	3	2.5	3	2.
	Min.	S	0	0	0	0	0	0	0
		D	0	0	0	0	0	0	0
$\%0_2$ Saturation	Max.	S	102	100	96	92	91	93	104
		D	112	98	97	90	87	91	90
	Mean.	S	98	92	88	86	85	85	85
		D	96	90	86	82	82	83	81
	Min.	S	86	81	82	80	78	76	74
		D	81	81	81	71	80	72	72

IVER.

13	14	15	17	18	19	20	21	22	23	24	25	26
30.5	35.0	39.5	51.5		60.5	69.5	78.5	88.0	98.0	130.5	145.5	148.0

KESBURY RIVER JUNE, 1947.

TION OF SUBSTANCES IN BOTTOM DEPOSITS.

20		26	24	56	29	32		31		37		
1.2		1.6	2.3	3.0	2.3	2.4		2.6		2.8		
44		80	88	5	21	13		14		28		
18		19	11	11.3	15	19		15		18		
310		280	280	470	390	590		510		560		
6		0	0	0	0	0		0		0		
0		0	0	0	0	0		0		0		

RIVER, 1946.

AIN PROPERTIES OBSERVED THROUGHOUT THE YEAR.

14.4	12.2	9.5	1.5	1.2	0.1	0.3	0.1	0.1	0.1	0.1	0
14.8	12.4	9.6	1.6	0.4	0.3	0.5					
10.8	8.4	6.0	0.8	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0
11.6	8.8	6.0	0.8	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0
4.4	2.0	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0
6.3	3.0	0.5	0.1	0	0	0					
26.8	26.8	26.8	27.1	28.3	26.3	26.7	26.7	26.3	26	16.3	28.0
27.0	27.0	27.0	27.3	27.8	27.1	27.0	—	—	—	—	—
19.7	19.7	19.7	20.0	20.0	19.1	19.2	19.5	19.4	18.2	163	18.2
19.4	19.4	19.5	20.0	20.0	18.8	19.2	—	—	—	—	—
13.5	13.5	13.5	13.5	12.0	10.5	10.6	10.6	11.2	10.4	10.2	10
13.5	13.5	13.0	12.8	10.7	10.5	14.0	—	—	—	—	—
665	665	900	880	450	320	310	290	400	1320	250	130
510	680	900	680	600	250	320					
220	240	250	315	190	110	115	100	120	440	70	60
195	240	250	280	220	110	130					
5	3	2	25	2	2	2	2	5	15	10	2
1	2	2	1	1	1	10					
13	—	10	23	20	12	22	13	18	20	10	25
5	—	32	13	24		30					
5	—	4	6	9	9	12	9	9	11	6	11
3	—	9	6	12		11					
0	—	0	0	1	4	4	6	4	3	1	4
0	—	0	0	0		4					
2	3	3	3	3	4	5	1	1	10	3	
4	3	2	6	2	15	1					
0	1	0	1	0	4	2	1	1	10	3	
1	0	0	1	0	2	0					
0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0					
93	89	89	93	95	96	95	102	93	110	100	
	88	88	90	95	94	93					
80	80	80	85	88	90	84	87	87	78	92	
81	79	80	82	84	84	82					
72	71	70	68	69	77	70	53	72	62	60	
78	70	69	71	71	65	66					

TABLE 5.

Station Number.			1	2	3	4	5	6	7	8	9	10	11
Distance			0	2.0	5.0	8.5	12.5	17.5	28.5	41.5	55.0	60.0	90.2
(1) RICHMOND RIVER JANUARY, 1948. LONGITUDINAL DISTRIBUTION OF CERTAIN PROPERTIES													
(1)	Cl‰	S	19.3	19.3	13.1	11.4	6.7	1.4	0.1	0.1	0.2	0.1	0.1
		B					7.4		0.1	0.1			
	Water Temp. °C	S	22.2	22.3	26.6	26.5	27.0	26.0	26.0	26.3	27.0	26.7	27
		B					26.3	26.0	25.7	26.3			
	NO_3N	S	0	11.2	41.6	7.0	2.8	7.6	2.8	4.6	14	6.9	4.4
		B					3.5		3.5	0.5			
	PO_4P Inorganic.	S	18.0	18.0	45.0	28.0	33.0	40.0	45.0	46.0	94.0	87.0	76.0
		B	—	—	—	—	34.0	—	43.0	44.0	—	—	—
	PO_4P Organic.	S	0	4.0	0	0	0	5.0	3.0	12.0	0	0.8	5.0
		B	—	—	—	—	0.5	—	6.0	4.0	—	—	—
	$\%O_2$ Saturation	S	101.0	98.5	94.0	100.0	99.0	83.0	86.0	83.0	80.0	82.9	90.0
		B	—	—	—	—	93.0	—	84.5	82.4	—	—	—

(2) RICHMOND RIVER, LONGITUDINAL DISTRIBUTION OF SUBSTANCES IN THE BOTTOM DEPOSITES OF RICHMOND R. ESTUARINE SYSTEM.

(2)	Organic C. mg/gm Silt.	0	28.5	17.2	18.5	—	15.5	12.5	13.3	—	11.5	13.0
	Total N. mg/gm Silt.	0	2.1	1.2	1.6		2.15	1.2	1.2	—	1.8	0.85
	Silt %	2.0	10.0	13.6	47.5		52.4	60.0	43.6	—	15.0	14.8
	Fe Iron mg/gm Silt.	9.9	5.0	105.0	35.0		29.0	12.5	67.5	—	44.0	59.2
Phosprates	Adsorbed P. ugm/gm Silt.	10	37	5	61		209	156	245		189	94
	Total P. umg/gm Silt.	620	765	460	500		885	155	225		880	880
	Interstitial P. ugm/gm Mud.	32	16	34	1		16	6	7		17	9

(3) RICHMOND RIVER, FEBRUARY, 1947. LONGITUDINAL DISTRIBUTION OF CERTAIN PROPERTIES.

(3)	Cl‰	S	10	9.1	5.2	—	1.1	0.1	0	0.2	0
		B	10	16.8	—	—	1.1	0.1	0	—	—
	Water Temp. °C	S	24.2	24.5	25.1	25.9	26.9	28.0	27.8	25.3	25.3
		B	24.5	25.4	—	—	26.9	27.4			
	NO_3N	S	22	111	119	—	160	225	278	310	275
		B	35	29	—	—	160				
	Inorganic PO_4P	S	32.0	39.0	63.5		52.0	58.0	52.0	43.0	55.0
		B	40.0	22.5			58.0	52.5			
	$\%O_2$ Saturation	S	72	63	60	—	37.5	23	20	45	60
		B	44.5	77.5	—	44.5	29.5				

TABLE 6.

SWAN RIVER.

Station Number.			1	2	3	4	5	5a	6	7	8	9	9a	10	11	12	13
Distance.			0	2.4	4.4	6.4	9.6	10.4	11.0	12.2	14.6	17.0	19.4	21.8	23.8	25.6	30.6
(1) SWAN RIVER 1947. MAXIMUM, MEAN & MINIMUM VALUES OF CERTAIN PROPERTIES OBSERVED THROUGHOUT THE YEAR.																	
Cl%	Max.	S	20.3	20.0	20.0	19.8	19.8	19.6	19.4	19.1	17.75	14.4	12.74	12.2	8.9	5.7	3.7
		D	20.35	20.0	20.0	22.2	19.7	19.6	19.6	19.6	18.8	—	—	14.0			
	Mean.	S	18.6	14.6	13.0	12.4	10.9	10.6	10.5	10.2	8.2	5.2	4.7	4.3	3.0	2.2	1.8
		D	19.6	16.7	17.4	18.25	18.0	15.9	14.0	13.3	9.5	—	—	4.7			
	Min.	S	14.30	2.00	0.80	0.80	0.75	0.50	0.74	0.85	0.85	0.55	0.67	0.70	0.67	0.70	0.70
		D	18.7	8.4	15.2	14.0	16.1	1.9	1.6	0.85	0.8	—	—	0.7			
Water Temp. °C	Max.	S	22.8	23.0	23.5	23.7	23.9	25.7	23.8	24.0	25.5	27.6	28.2	28.0	29.3	—	27.2
		D	22.3	23.5	23.3	23.1	23.1	24.1	22.8	22.1	24.7	—	—	28.9			
	Mean.	S	19.6	19.0	18.9	19.0	18.8	20.2	18.8	18.6	19.4	19.3	19.6	19.5	19.6	18.7	18.5
		D	19.2	19.2	19.1	19.1	18.9	19.3	18.3	18.5	19.3	—	—	19.7			
	Min.	S	15.2	14.4	14.2	14.1	14.1	14.5	14.0	13.9	13.9	13.9	13.4	13.2	13.7	12.6	12.5
		D	15.3	15.4	15.4	17.0	16.7	16.7	14.2	13.8	13.8			13.0			
NO_3N	Max.	S	25	255	255	278	324	148	252	260	326	515	578	575	575	669	675
		D	16	193	99	286	243	242	315	716	222			576	—	—	—
	Mean.	S	14	60	62	63	60	45	50	72	125	163	155	155	155	148	152
		D	10	33	32	52	70	70	70	72	111			174			
	Min.	S	0	7	6	6	5	1	5	8	—	11	7	7	8	6	3
		D	0	2	6	7	5	5	6	5	4	—	—	5	—	—	—
Inorganic PO_4P	Max.	S	6	18	20	18	19	20	23	23	30	57	57	43	33	28	21
		D	6.0	16.0	14.0	13.5	13.0	40	16.0	42.8	34	—	—	40.0	—	—	—
	Mean.	S	1.2	5.4	5.4	5.3	5.4	6.5	7.0	7.0	13.0	23.0	19.5	14.0	11.0	9.0	6.0
		D	2.0	4.3	4.4	5.1	5.1	11	5.1	10.0	13.0	—	—	13.0			
	Min.	S	0	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.2	1.3	0.1	0.1	0.1	0.1
		D	0.1	0.1	0.1	0.1	0.2	0	0.2	0.3	2.3	—	—	0.5			
$\%O_2$ Saturation	Max.	S	103.0	100.0	102.0	106.5	106.0	111.0	105.0	98.0	98.0	96.0	117.5	94.5	89.0	91.0	89.0
		D	105.5	101.0	102.0	90.0	101.0	102.0	92.0	86.0	96.0	—	—	110.0			
	Mean.	S	96.0	93.0	92.0	91.0	91.0	91.0	89.0	84.5	77.0	75.5	81.0	80.2	78.0	78.0	63.0
		D	97	94	93	77	65	62	71	68	71	—	—	80			
	Min.	S	89	84	80	73.4	73	65	63	69	60	60	61	65	60	65	58
		D	89	88	82	49	23	17	38	20	50	—	—	63	—	—	—

TABLE 6 (2)

Station Number		1	2	3	4	5	6	7	8	9	10	11	12	13
(2) DISTRIBUTION OF SUBSTANCES IN BOTTOM DEPOSITS, SWAN RIVER, AUGUST 1946.														
PO_4P	Total P. ugm/gm Silt.	639	742	590	610	887	468	489	439	800	268	342	361	143
	Ads. P. ugm/gm Silt.	1	0	42	25	67	60	66	52	214	7	54	1.5	1
	Int. P. ugm/gm Silt.	1.0	2.0	28.0	1.0	60.0	1.0	4.0	1	1.5	1.5	1.5	1.5	1
Organic C.	mg/gm Silt.	5.5	28.5	29.0	27.5	35.0	25.0	32.5	35.0	46.0	14.4	25.0	28.0	4.0
Total N.	mg/gm Silt.	2.1	3.5	2.7	4.9	4.45	2.6	2.9	3.5	3.4	1	2.4	2.4	0.35

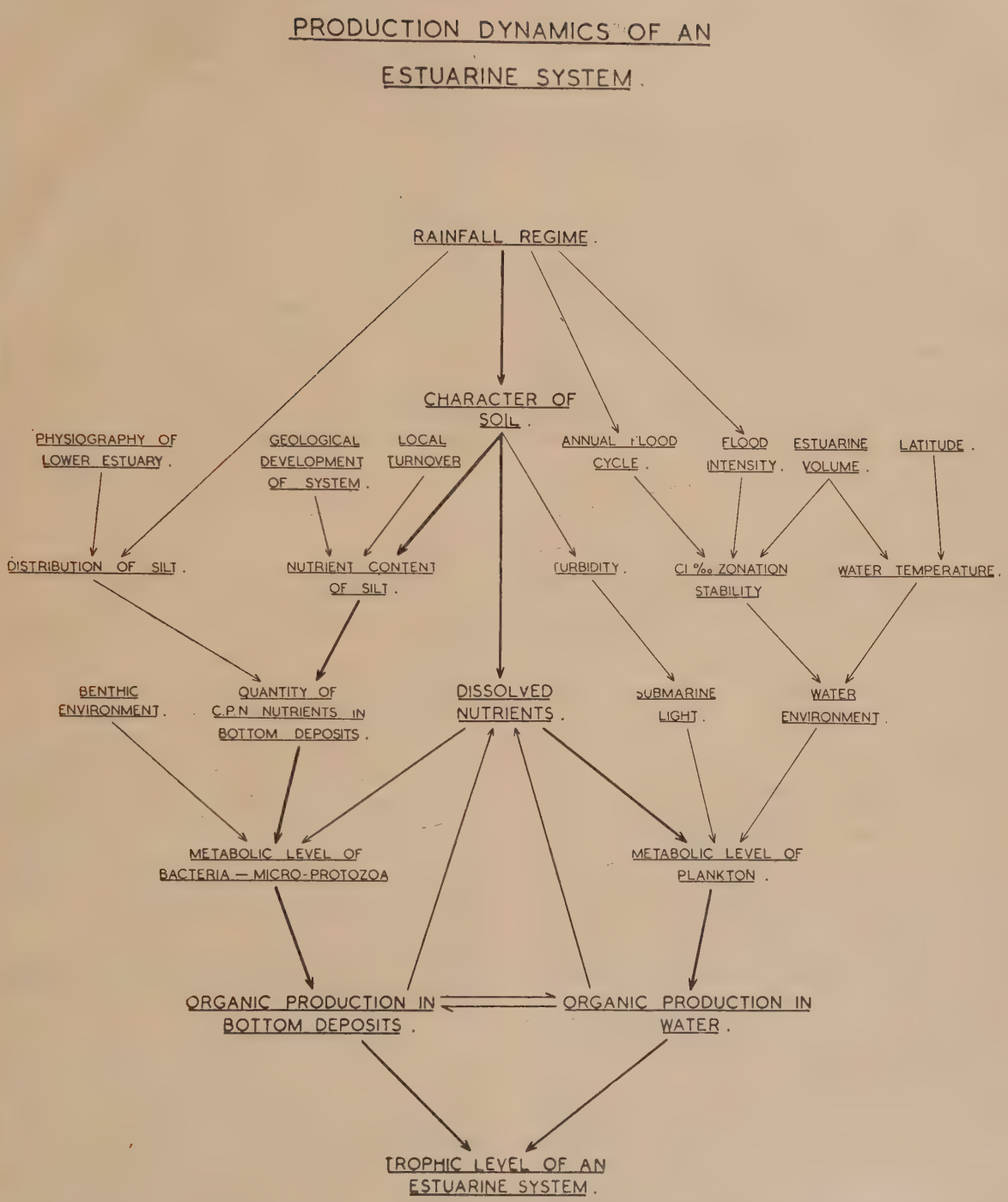


Fig. 10. Diagram illustrating the relationships beween edaphic, meteorological and hydrological factors in the productivity of a typical Australian estuarine system.

douces et salsees. L'Institut Oceanographique *Bull.* No. 917.

TULLY, J. P., (1949) .—Oceanography and Prediction of Pulp Mill Pollution in Alberni Inlet. Fisheries Res. Board Canada *Bull.* No. 83.

NASH, C. B., (1947) .—Environmental characteristics of a river estuary. *J. Mar. Res. 6*: 137-174.

MOORE, H. B., (1930) .—The muds of the Clyde Sea area. I Phosphate and nitrogen content. *J. Mar. Biol. Assoc.* n.s. *16*:

MOORE, H. B., (1931) .—The muds of the Clyde Sea area. III. Chemical and physical conditions; rate and nature of sedimentation and fauna. *J. Mar. Assoc.* n.s. Vol. 17.

APPENDIX

CHEMICAL METHODS AND UNITS

Since a detailed description of the chemical methods followed in the determination of estuarine hydrological properties is given in a paper now ready for publication by C.S.I.R.O., Melbourne, no description of analytical procedures is contained in this Symposium paper. It is necessary, however, to detail the units employed in the description of these hydrological properties:—

Temperature	Express in °C.
Chlorinity	Expressed as parts per thousand or % of titratable halides.
Phosphates	Expressed as /ugm./L. PO_4P
Nitrates	Expressed as /ugm./L. NO_3N
Dissolved 0xygen	Expressed as mls./20° litre at N.T.P.
% Saturation	Calculated by the use of Fox's saturation tables
Interstitial) Phosphates Adsorbed) in bottom Total) deposits	Expressed as /ugm. PO_4P/ gm. silt
Total ferric iron) In Total nitrogen) bottom Organic carbon) deposits	Expressed as mgm./gm. silt

---

2

PHYSIOLOGICAL ASPECTS OF ADAPTATION TO ESTUARINE CONDITIONS

by

N. Kesava Panikkar*

INTRODUCTION

It is fairly well known that animal life associated with estuaries is highly developed so as to form a specialised fauna under tropical conditions. In the continent of Asia, this fauna includes a large variety of species, often occurring in large numbers in the various subdivisions of the estuarine habitat. The concensus of opinion is that this fauna does not attain the same high development in temperate waters even though there are the examples of fauna associated with low salinites as found in the Baltic Sea. Similar groups of organisms probably exist in other continents as well, associated with the openings of large rivers into the sea or with lakes having permanent or temporary connections with the sea, contributing to areas of high biological productivity. The fauna associated with the estuarine habitat has been investigated by a great many workers in India (vide Annandale et. al., 1915-1924; Sewell, 1934 and Panikkar & Aiyar, 1937 for lists of animals and literature) and it is possible to say that the faunal elements are fairly well understood at the present day, although the subdivisions of this fauna on the basis of salinity distributions as demarcated by Redeke (1922) and the physiological behaviour of the species are not known. Only in comparatively recent times had the interest in this fauna in relation to exact environmental conditions and to the physiology of the species concerned come to the forefront of faunistic and ecological studies.

PHYSICAL FEATURES OF ESTUARINE HABITAT

For the purpose of assessing the physiological factors in the light of adaptation to estuarine conditions the scope of the estuarine habitat need not be confined to estuaries themselves but could be enlarged considerably to include, (1) the estuaries proper associated with rivers opening into the sea and where, by the influx of large volumes of fresh water into the sea, a zone of low salinity is created, the extent of this zone varying according to the size

* Central Marine Fisheries Station, Mandapam, S. India.

of the river, the steepness of gradient and the tidal range (2) lakes which receive fresh water from rivers but may have a permanent connection with the sea and exhibit a salinity gradient from sea water to water that is nearly fresh (3) lagoons or backwaters occurring close to the shore and connected with the sea during periods of flooding but becoming cut off during drought and (4) salt marshes developed from smaller lagoons or backwaters by large-scale evaporation of water. As an example of the first we could mention the deltaic basin of the rivers Ganges and Brahmaputra; the Chilka Lake on the East Coast of India is an example of the second category while the numerous backwaters and saline lagoons found all along the Indian Coasts would broadly fall into the third and fourth categories. It is needless to mention that the habitats comprehended under these four conditions include a wide variety of sub-habitats, but from the point of physiology of the animals inhabiting them they have one thing in common i.e. wide variations in the salinity of the external medium. The problem of physiological adaptation of life under estuarine conditions is largely a question of adjustments to meet the changes in external conditions brought about by changes in salinities both from the point of view of reduced osmotic pressure and from the deficiency of salts for physiological processes.

TEMPERATURE AND SALINITY

The second factor of interest to us is temperature which ranges normally on tropical coasts from about 25° to 30°C and, in fact, the annual variations are mostly within 4°C as compared with the range of about 16°C in colder waters. Both salinity and temperature are affected by the prevalent currents on the coasts, the volume of water discharged into the sea and the volume of sea water that invades fresh water during high tide, especially in areas where the currents are favourable. While there is considerable movement of water in the first category of estuaries, a great deal of stagnation, except for movements produced by convection currents, is associated with lakes and salt marshes. Smaller volumes of water are subject to fluctuations caused by the opposing factors of flooding and evaporation. The relative proportion of salts in estuaries and in salt marshes need not be the same as in sea water (Howes, 1939); there is a significant increase in the amount of sulphates at the expense of the chlorides. There has been a common belief that the estuarine water need be considered only as sea water diluted with fresh water, but recent work in different parts of the world has shown that owing to differential precipitation during evaporation, which may occur a number of times in any given body of water, the proportion of salts tend to be different from that found in normal sea water (Beadle, 1943). This difference in the proportion of ions is further accentuated in the case of inland saline waters. Sufficient information is lacking as to how far this has contributed to the evolution of different types of estuarine fauna.

Another factor worth mentioning is the localization of the saline habitat in an estuary. Salt water may extend for several miles up the river as in the Ganges and, in this instance, the influence of fresh water is also felt for several miles into the sea at the head of the Bay of Bengal where the salinities are profoundly altered, even affecting up to a depth of about fifty fathoms (Sewell, 1934). While in the estuary itself the surface layers may remain fresh or of low salinities, high salinity conditions often prevail in the silt laden region of the bottom. Under such circumstances it may not be surprising to come across typical marine examples of animal life in the bottom while in the surface waters the animals may be very different consisting of freshwater and brackish-water species.

A feature associated with salt marshes is the question of desiccation during summer, when they may completely or partly become dry. There will be progressive increase in the salinity of the water, often reaching values much higher than sea water. The survival of species under these conditions is dependent upon special adaptations to tide over the period of drought. In a large majority of such coastal inlets or lagoons, the colonization of animals is an annual feature taking place during the favourable months of the year and continuing till the period of drought. Except where complete drying occurs, most species adjust to temperature changes either by migrations to colder areas or by burrowing to different levels or even by aestivation.

FAUNAL ELEMENTS OF ESTUARIES

The animals found in the estuarine habitats comprise three distinct categories: (1) true estuarine species which have made low salinity waters more or less their permanent home (2) marine species which can survive a certain amount of changes in the external medium which may either be brought about passively or by active physiological adaptation and (3) freshwater species which are capable of surviving a certain amount of salts in the external medium. This classification cannot be rigid because we find many instances of migratory species passing through the estuaries to or from the sea or coming there for purposes of feeding or spawning.

In the tropical coasts most of the major marine invertebrate phyla with the exception of the Echinodermata and the Brachiopoda are represented in the estuarine fauna and a study of any such area will reveal that the species under the first two groups

are predominantly marine. From the point of view of the fisheries may be mentioned the Crustacea which includes several species of commercially important prawns of the family penaeidae (*Penaeus* and *Metapenaeus*) and crabs of the family Portunidae (*Scylla and Neptunus*). Among the Mollusca, oysters and clams abound in the estuarine habitat includ- the well known genera *Ostrea, Meretrix, Circe* and *Modiola*. Among fishes, the elasmobranchs are very poorly represented, but a very large number of teleosts are found including several Clupeoid species (Elopidae, Chanidae, Clupeidae and Engraulidae), gobioids, percoids, mugils, polynemids, hemirhamphids and pleuronectids. The estuarine fishes *par excellence* are the Gobiformes many of which are not only resistant to abrupt salinity changes but also include species which have developed powers of aerial respiration and are able to survive exposure to air for considerable periods. The freshwater families of fishes, the siluroids, the cichlids (*Etroplus*) and the freshwater prawns of the family Palaemonidae (*Palaemon* and *Leander*) are forms of fishery interest among the animals of freshwater origin that become associated with the estuarine habitat. (See Anandale & Kemp 1915-24 (Chilka Lake); Hardenberg, 1949 (Fishes of Indonesia); Sewell, 1934 (Salt Lake Fauna of Calcutta, more especially Copepods); Panikkar and Aiyar, 1937 (Madras brackishwater Fauna).

ADJUSTMENTS TO LOW SALINITIES

It has already been indicated that the most essential adaptation for an animal before it can become estuarine is that of adjustment to changes in salinities. Most marine invertebrates are not able to tolerate changes in their external medium because they are in osmotic equilibrium with the surroundings and are unable to prevent corresponding changes taking place in their internal medium. When in low salinities, the low osmotic pressure of the surroundings results in their swelling by water invading the tissues and salts from the body escape to the exterior by diffusion. The problem presented by marine animals when in waters of reduced salinity is that of being able to maintain its tissues in a state of functional activity in defiance of the changes taking place outside. We can recognise a few variants in the types of adaptations which have actually taken place in marine animals before they have established under estuarine conditions.

ADAPTATION WITHOUT OSMOREGULATION

The simplest process will be to find means whereby tissue adaptation is possible even under low salt concentrations. This is the method resorted to by a small number of invertebrates which, if acclimatisation is spread over of prolonged period, are able to withstand gradual reduction of salinities by appreciable levels. Examples of this category of adaptation where there is no osmoregulation are from the Mollusca (e.g. *Mytilus edulis*) and the Polychaeta (e.g. *Arenicola marina*) and it probably occurs in many other lower marine invertebrates occurring in many parts of the world (Valikangas, 1933; Schlieper, 1935). Adaptation in these cases is possible only up to a certain dilution owing to the fact that in the absence of regulation the animals cannot survive in salinities below their own threshold concentrations.

HYPER-OSMOTIC REGULATION

The vast majority of animals which we come across in estuaries show, however, a definite mechanism of adaptation directed to maintaining the body fluids. Among the marine animals that main- relative independence of the concentration of their tain osmotic equilibrium with the surroundings in sea water there is a very considerable number of species which are able actively to regulate their salt contents to levels higher than the surroundings when the external salinities are low. This may be termed *hypertonic* or *hyper-osmotic* regulation and the degree to which the hypertonicity is maintained is often a measure of the adaptation of the species. Well known examples of this type of osmotic regulation are those of euryhaline crabs like *Carcinus* which has been the objective of study by several workers (Webb, 1940) and in invertebrates belonging to several phyla (Krogh, 1939). The highest degree of hypertonic regulation will of course be found in those animals which can inhabit fresh water. It is possible to come across instances ranging from complete absence of regulation to extremely well developed hyper-osmotic regulation in the numerous species that inhabit the estuaries.

The beginnings of acclimatisation to low salinities may be seen in marine species which are coastal as against oceanic, especially in areas where the coastal salinities are appreciably altered by freshwater influence. This circumstance of slow acclimatisation has been a notable factor in the evolution of osmoregulatory functions involving permanent adaptations to low salinity conditions which is distinct from temporary adjustments enabling species to survive changes for short periods.

HYPO-OSMOTIC REGULATION

A small number of marine invertebrates are not in osmotic equilibrium with their surroundings but have their body fluids maintained at a lower salt concentration. This type of osmotic regulation may be termed *hypotonic* or *hypo-osmotic* and has so far been found only in the Crustacea and in insects

inhabiting sea water. This represents probably the most elaborate osmotic mechanism ever perfected by invertebrates and is the nearest approach among invertebrate groups to adaptations seen in teleosts. Recent work has shown that the power of hypotonic regulation in the Crustacea is much more widely distributed than is usually known. Hypotonic osmoregulation was first discovered in an Australian estuarine crab, *Heloecius cordiformis,* by Dakin and Edmonds (1931) and other instances of such semi-terrestrial and estuarine crabs were reported by a few other workers (vide Panikkar, 1941 for full list—Dakin, 1935, and Krogh 1939), the classical instance being *Eriocheir sinensis* the Chinese wool-handed crab which is now widely distributed in European estuaries. It was generally assumed that this condition is confined to estuarine and semi-terrestrial invertebrates and it was, therefore, of unusual interest to find that the common marine prawn of European seas *Leander serratus,* was hypotonic in sea water as also the related species *Palaemonates varians* and *Leander squilla.* Species of the Palaemoninae are distributed in fresh water, brackish water and sea water and it seems probable that hypo-osmotic regulation is to be found in the marine and estuarine Palaemoninae. This is not so for all the prawns, because *Pandalus montagui* and *Pandalina brevirostris* both from the Plymouth coast but not entering estuaries show no osmotic behaviour typical of marine invertebrates, being isotonic with sea water (Panikkar, unpublished observations). On the other hand *Crangon vulgaris,* the European shrimp, has a regulatory mechanism similar to that of *Leander* (Broekema 1942, Panikkar unpublished), and the recent work we have carried out at Madras indicates that hypo-osmotic regulation also occurs in *Metapenaeus monoceros,* the common Indo-Pacific prawn (Panikkar and Viswanathan, 1948), and to a less marked extent in other marine penaeid species which enter the estuaries viz *Penaeus indicus* and *Penaeus carinatus* and *Metapenaeus dobsoni.* The essentials of hypo-osmotic regulation are that when in sea water, the animals regulate their blood concentrations to levels appreciably lower than that of sea water so that entry into brackish water for such animals does not involve an additional osmotic work. The advantages which they have for colonising estuarine waters is obvious. Other groups of Crustacea in which hypo-osmotic regulation has been observed are the brine shrimp Artemia and the Grapsoid and Ocypodid Crabs (Jones 1941) which are characteristic inhabitants of coasts and estuaries surviving exposure to air for long periods and showing modifications in their respiratory organs. Low salt content of blood would appear to be of definite advantage to these amphibious species which are subject to desiccation because the difference between the natural concentration and the maximal concentration of their blood compatible with life is always high providing for a wider safety limit. While all these same animals are in waters of salinities lower than their isotonic points, they exhibit marked powers of hypertonic regulation, thereby proving the existence of mechanisms which operate in both directions. It is not surprising therefore to find the two grapsoids *Eriocheir sinensis* and its close Indian relative *Varuna litterata* showing a similar osmotic behaviour (Panikkar unpublished) successfully penetrating into estuaries and fresh waters in Europe and in India.

ACTIVE REGULATION OF CHLORIDE

Investigations carried out on *Metapenaeus monoceros* have revealed that its homoiosmotic behaviour is largely brought about by the active regulation of the chloride ion in its body whose level is kept fairly constant in spite of the wide variations that might take place in the surroundings. Theoretically one would expect that the amount of chloride in sea water and the body fluid of a marine invertebrate will be of about the same order, except for the slightly lower values for blood brought about by the non-diffusible serum proteins in blood contributing to the Donnan Equilibrium. But a difference in chloride concentration of the order of 0.8% NaCl between blood and sea water could not be brought about passively and can only be the result of active exclusion of chloride from the body into the surrounding medium in the same manner as some kind of active uptake of chloride is clearly indicated when the same animal is in freshwater or of low salinities.

ACTIVE TRANSPORT OF IONS

The subject of active ion transport across animal membranes (vide Ussing, 1949 for a recent review) which has made important strides in recent years, ever since it was first demonstrated in aquatic animals by Krogh and his collaborators at Copenhagen, is of interest in this connection because we have here one of the mechanisms which enables both hypertonic and hypotonic regulations to be performed. It is especially significant for animal life in fresh water and in brackish water as we now have a large body of evidence to show that the ability of aquatic animals to assimilate chloride ions (which is not unlike the anion-atmung demonstrated by Lundegardh in plants), even when the latter are present only in exceedingly minute quantities, would account for their blood salt levels being maintained at relatively higher than the surroundings. It is not my intention to minimise the role of the excretory organs in osmoregulation but in estuarine invertebrates which largely produce a urine isotonic with blood the kidneys can, to my mind, be assigned only

a secondary role, except in transient adjustments where they actively retard the osmotic accumulation of water. The position is different in fresh water invertebrates where the ability to produce copious amounts of dilute urine deficient in chlorides will be of equal physiological value as salt absorption.

ESTUARINE VERTEBRATES

Among the Chordates, no Prochordate is known from estuarine waters. As regards the vertebrate groups there is the fundamental difference between their osmotic behaviour and that of marine invertebrates because the vertebrates are not in equilibrium with the surrounding sea water but have salt concentrations far below that of the environment. The marine teleosts have their osmotic pressures varying only from about 1.2 to 1.7% NaCl in normal sea water which has called for special mechanisms of adaptations on their part to cope with the continual loss of water to which they are subjected to by living in a hypertonic medium. The marine elasmobranchs on the other hand are either slightly hypertonic or isotonic although their salt concentrations are of about the same order as that of teleosts, the difference in osmotic pressure being made good by accumulated amounts of urea in their blood. These facts which have emerged from the work of Homer Smith are now well known to students of physiology and have their impact on the ability of marine teleosts and elasmobranchs to enter fresh water.

SHARKS AND RAYS

Only a small number of species of sharks and rays are known to enter the estuarine and fresh waters owing probably to their delicate osmotic properties and even in the species known to enter rivers several miles above tidal influence, the evidence available to prove that they are permanently established in fresh water requires re-examination. Their ability to undertake sojourns into fresh water seems to be connected with the power of the kidneys to reabsorb urea and to excrete large amounts of very dilute urine as found in *Pristis microdon* (Smith & Smith vide Krogh, 1939).

BONY FISHES

From the fact that the teleosts have hypo-osmotic regulation one may be inclined to think that as a group they would find it relatively easy to tolerate salinity changes at least up to the limit of their own salt concentrations. But if we compare the estuarine with the marine fish fauna it will be apparent that only a relatively small number of marine teleosts have succeeded in securing a foothold in the estuaries. This is partly because the adaptation in marine teleosts is itself a complex process involving extra renal secretion of salt through the gills and active drinking of sea water to make good the water loss by diffusion (Smith, 1930; Keys, 1933; etc.). Changes from one medium to the other may call for differences in the functional activities of the osmoregulatory centres which have developed only in certain groups of teleosts. In a large measure this has been achieved by modifications in renal function as reflected in structural improvements in the glomeruli and kidney tubules. Physiological evidence is that the teleosts must have originated in fresh water from where a large section colonized the sea and the many fishes at present estuarine are examples of recent recolonization of the estuaries by marine fishes.

Extreme instances of adaptation in marine fish are to be found in the species which migrate to fresh water for spawning like the salmon and the Hilsa and those journeying far out into the sea from fresh water like the eel on which much work has been done. Krogh (1939) summarising the available information says that "the peculiarities which are responsible for this power are not at all clear in spite of the considerable amount of work spent upon the problem" (p. 147).

In India, the most noteworthy instances of teleosts of marine origin which live in estuarine waters and can tolerate large variations in salinities as seen from field observations are *Chanos chanos Mugil sp., Elops indicus, Magalops cyprinoides, Engraulis purava, Lates calcarifer and Polynemus tetradactylus,* to mention but a few examples, but it is regrettable that even the salinity ranges of some of these well known coastal species are unknown.

CHANOS CHANOS

We have recently started investigations along these lines at the Central Marine Fisheries Research Station and it is possible to report a few preliminary results on *Chanos chanos* based on recent observations (Panikkar, Viswanathan & Tampy unpublished). Our experiments indicate that *Chanos* is able to live in waters of salt concentrations varying from nearly fresh water to salinities as high as fifty parts per thousand and that within its range it is capable of transfers from one medium to the other without acclimatisation. Within the wide range of external concentrations of chloride of nearly 5% NaCl, the variations taking place in its blood are within 0. 5% NaCl, showing, similar to *Metapenaeus* cited above, an extraordinary ability to regulate the chloride content of its blood involving presumably active elimination of these ions in hypertonic and active uptake of ions in hypotonic media. Fish are able to live only in water containing small amounts of chloride without which the regulatory mechanism

breaks down. These highly developed adaptational powers of this species have been utilized for centuries in the fish cultural practices of South East Asia and its tolerance to salinities higher than normal sea water as found from our laboratory experiments would also seem to indicate its value in stocking saline coastal lagoons.

FRESHWATER INVERTEBRATES IN ESTUARIES

The groups of animals which have entered the estuaries from fresh water remain to be considered. Among the invertebrates several species of *Palaemon* migrate to brackish water during the spawning periods in the Chilka and Collair lakes of India and are often collected along with Penaeids which have migrated from the sea.

One of the most important properties of freshwater organisms is the ability to maintain at a constant level the salt concentrations of their bodies in a medium that is relatively dificient in salts. The main lines of adaptations are the relatively low permeability of the integument, the active absorption of chloride ions from the surroundings and the elimination of excess water from the body by the production of copious amounts of hypotonic urine, which is largely made possible by the reabsorption of salts from the nephridial canal before the discharge of the urinary fluid. In general it may be stated that among the invertebrates which have entered estuaries from fresh water, specialised types with a normally low osmotic concentration are absent, but include only forms whose existence in fresh water itself has only been comparatively recent and show a relatively high concentration even in fresh water. It is possible to say that in the freshwater Palaemoninae adaptation to fresh water has been achieved without much modification in the excretory mechanism, a fact which was probably of advantage in their entry into saline waters (Panikkar, 1941).

Among the freshwater molluscs which are at home in salt water are numerous species of hydrobiid and melaniid molluscs (Gastropoda) but the mechanisms of adaptation are unknown.

FRESHWATER FISHES ENTERING ESTUARIES

The behaviour of certain freshwater teleosts when they are acclimatised to salt water by slow increase in salinities throws some light on the types of species which have been able to establish in the estuaries. Duval (1925) gradually acclimatised carp in salt water and studied the osmotic concentration of carp blood in media varying from the normal fresh water to salt water having approximately half the salinity of the sea and found that the fish is hypertonic to the medium till about 1. 2% NaCl when isotonicity is reached; in external concentrations higher than this the fish is isotonic with the surroundings and not hypotonic as we find in the case of adaptable forms like *Anguilla* and *Chanos*. Obviously in the carp there is no mechanism of hypotonic regulation involving active elimination of salt and it would appear that the toleration of teleosts to higher salinities has been possible only in the case of species which have developed the power of hypotonic regulation. Such modifications in behaviour may be expected in the estuarine Siluroids and the two cichlid fishes *Etroplus maculatus* and *Etroplus suratensis* which, although belonging to a freshwater family, are common brackish-water species in India, able to live even in sea water, but not found in the open sea. The colonization of the sea by marine fishes was possible only by the perfection of hypo-osmotic regulation in their original home. Much further physiological work on families of fishes which have become estuarine in recent times will be necessary before the mechanism of adaptation in the different families could be adequately explained.

TEMPERATURE AND OSMOTIC REGULATION

While considering the question of osmoregulation of estuarine species, it is essential to note how factors other than salinity might affect the process of osmotic adjustments. Among these external factors the most important is the temperature. Does adaptation to low salinity take place more easily at higher than at lower temperatures? There is first of all the body of evidence presented by the much better developed estuarine fauna of the tropics. This has often been explained by the familiar hypothesis of Von Martens that the relative evenness of temperature of tropical waters, characterised by the absence of periods of sharp winter and the presence of large rivers opening into the sea and by heavy rainfall, has been the main contributory causes of the development of a rich estuarine fauna. Recent investigations have, however, brought to light that the question of adaptation to changes in salinities on the part of coastal species is also probably influenced by temperature. Evidence in favour of this has been presented by Broekhuysen (1936) (who has also summarised the earlier literature) who while studying *Carcinus maenas* on the Netherlands coast found that there is in the distribution of this species an unmistakable inverse correlation between temperature and salinity. Similar results have been obtained by Broekema (1942) who made a careful analysis of the distribution and physiology of the shrimp *Crangon vulgaris*. The shrimps are found in the northern regions of the North Sea i.e. in high salinity waters in winters. In spring a general migration takes place into brack-

ish water where the animals remain throughout the summer months returning again to the more saline regions in the autumn. It would appear that high temperatures are favourable for the penetration of both these animals into low salinity regions and that during conditions of winter, high salinity is invariably preferred. There are several instances of marine crustacea of colder waters being represented in tropical areas by brackish water or freshwater species. The physiological processes responsible for this influence of temperature on salinity as affecting the distribution of animals have not yet been understood. A seasonal cycle in the osmotic concentration of various crustacea involving a higher value in winter and a lower value in summer have been found by many workers (Panikkar, 1940 for earlier literature and Broekema, 1942). The ecological significance of these changes would appear to be that there is a shift in the optimal value of internal blood concentration when there are temperature changes taking place outside which fit closely with the observed differences in the concentration of the species mentioned above. It is not easy to define what an optimal concentration for a species is, but suffice to say that there is a difference in the amount of osmotic work performed by an animal on the basis of the inverse correlation between temperature and salinity. This is borne out by laboratory experiments where the mortality of animals when transferred from sea water to media of lower salinities is lower under conditions of higher temperature. Migrations within definite areas by estuarine animals may possibly be explained on the basis of this combined influence of temperature and salinity.

OSMOTIC REGULATION AND REPRODUCTION

A second aspect which needs attention in the normal adaptation of species is to find out how far the reproductive seasons have an influence on their processes of adaptation. A most interesting line of attack on this problem has been developed by Koch in Belgium (Koch & Heuts 1943, also for earlier references). Studying the stickleback and a few other species, it was found that there is a substantial modification of the osmoregulatory functions in animals which are sexually mature as well as in animals in which sexual maturity has been induced artificially by the administration of the thyriod hormone. In the case of the stickleback high salinity is not tolerated under such conditions which logically would mean that a sexually mature fish would be obliged to migrate into fresh water. In the case of prawns, I have found a higher optimal value among ovigerous females of *Leander serratus* than in non-ovigerous females (and in males) which probably indicates that the ovigerous prawns would prefer higher salinity conditions. It cannot at the present moment be clearly formulated how sexual maturity affects adaptational powers, but evidence is slowly coming from recent work in Koch's Laboratory to show that there are certain changes in the regulating mechanism at the time of sexual maturity in fishes. There is scope for a large amount of work in this direction because it might throw light on the phenomenon of migration and the stimulus necessary for migration in fishes and crustacea. The problem is complicated in the crustacea which undergo periodical moulting and exhibit osmotic cycles in relation to moulting (vide Panikkar, 1941).

INFLUENCE OF CALCIUM

The influence of accessory substances in the medium which affects the regulatory functions should also be mentioned. The most significant is the influence of the calcium in the surroundings which often enables an animal to penetrate into low salinity waters which it would be unable to do in the absence of this specific ion. This is already known for several aquatic animals and recent experiments which we have conducted on *Chanos* have shown that toleration of this fish to low salinity conditions is greatly facilitated in the presence of adequate supplies of calcium which is a point of practical value in fish cultural practices.

BIOCHEMICAL ADAPTATIONS

The permanent establishment of marine species in estuarine waters is also connected with the question of the efficiency of the osmoregulatory mechanism in the larval as well as adult phases of life history and of biochemical aspect of adaptation to freshwater life emphasized by Needham (1930). The provision of enough ash in the egg for complete development and organization of the embryo will be necessary in the new habitat because in the sea the marine animals normally depend upon the environment for their inorganic requirements. Only when both these requirements are met with in addition to the powers of the adult organisms to live in the new habitat, could a species physiologically succeed in becoming a permanent factor in the fauna will naturally be bound up with other biological factors as well, like availability of food and competition between different forms of animal life in the same biota.

CONCLUSION

The physiology of estuarine conditions, particularly the process of adaptation in estuarine species, is a subject which is of importance to us in the practical application of physiological principles in fish culture. Throughout the Indian coast, and this holds good for many other countries of the Asian

Continent, the coastline is characterised by the presence of numerous inlets and lagoons which, if properly utilised, would offer vast opportunities for cultivating fish on a large scale. The conditions in these areas are saline, but extremely variable as they are liable to flooding during the rainy season and to increase in salinities during the summer months. There is a certain amount of fish culture done in such areas based on empirical knowledge, as for example, the *Chanos* culture in South East Asia and the prawn culture of the Malabar Coast, but we are far from having the scientific data on which these practices could be perfected and developed, this being bound up with the selection of suitable species for culture, suitable species as accessory forms for food, optimal habitats for the organisms chosen and the chemical conditions which are essential for successful operations.

REFERENCES*

ANNANDALE, N., (1922).—"The marine element in the fauna of the Ganges" *Bijdr. t. Dierk.*, Amsterdam (Max Weber's Feest Number) 22.

ANNANDALE, N., S. Kemp, etal (1915-1924).—"Fauna of the Chilka Lake". *Mem. Ind. Mus.*, 5.

BEADIE, L. C., (1943) .—"Osmotic regulation and the faunas of Inland Waters". *Biol. Rev.*, 18.

BROCKEME, M. M. M., (1942 .—"Seasonal movements and the osmotic behaviour of the Shrimp, *Crangon crangon* L." *Arch. Neerl. Zool.*, 6.

BROCKHUYSEN, G. J., (1936) .—"On the development, growth and distribution of *Carcinides maenas* (L)". Ibid, 2.

DAKIN, W. J., (1935) .—"The acquatic animal and its evironmen". (Presidential addreses). *Proc. Linn. Soc. N. S. Wales*, 60.

DAKIN, W. J. & E. Edmonds, (1931) .—"The regulation of the salt contents of the blood of aquatic animals. and the problem of the permeability of the bounding membranes of the aquatic invertebrates". *Australian Journ. Exp. Biol. Med. Sci.*, 8.

DUVAL, M., (1925) .—"Recherches physico-chemiques et physiologiques sur le milieu interieur des Animaux Aquatiques. Modifications sous l'influence dua milieu exterieur". *Ann. Inst. Oceanogr. Monaco*, 2.

HARDENBERG, J. D. F., (1949) .—"The existence of an estaurine fish fauna in South East Asia". *Bijdr. t. Dierk. Amsterdam*, 28.

HOWES, N. H., (1939) .—"Ecology of a saline lagoon in South East Essex". *J. Linn. Soc. Zool*, 40.

JONES, L. L., (1941) .—"Osmotic pressure relations of nine species of crabs of the Pacific Coast of N. America". *J. Cell. Comp. Physiol.*, 18.

KEYS, A. B., (1933) .—"The mechanism of adaptation in the common eel and the general problem of osmotic regulation in ushes". *Proc. Roy. Soc.*, B. 112.

KOCH, H. J. & M. J. Heuts, (1943) .—"Regulation osmotiques, Cycle sexual et migration de reproduction chez les Epinoches". *Arch. Inter. Physiol.*, 53.

KROGH, A., (1939 .—"Osmotic regulation in aquatic animals". Cambrdige.

NEEDHAM, J., (1930) .—"On the penetration of marine organisms into fresh water" *Biol. Zbl.*, 50.

PANIKKAR, N. K., (1940) .—"Osmotic properties of the common prawn". *Nature*, 145.

————, (1940).—"Influence of temperature on osmotic behaviour of some crustacea and its bearing on problems of animal distribution". *Nature*, 146.

PANIKKAR, N. K., (1941) .—"Osmoregulation in some Palaemonid prawns". *J. Mar. Biol. Assoc.*, 25.

———— & Aiyar, R. G., (1937) .—"The brackish-water fauna of Madras". *Proc. Indian Acad. Sci., B.*, 6.

PANIKKAR, N. K. & R. Viswanathan, (1948) .—"Active regulation of chloride in *Metapenaeus monoceros* Fab". *Nature*, 161.

REDEKE, H. C., (1922) .—"Zur Biologie der Neederlandischen Brackwasser Typen". *Bijdr. t. Dierk.*, 22.

SCHLIEPER, C., (1933) .—"Neuere Ergebnisse und Probleme aus dem Geblet der Osmoregulation Wasserlebender Tiere". *Biol. Rev.*, 10.

SEWELL, R. B. S., (1934) .—"A study of the fauna of the salt-lakes in Calcutta." *Rec. Ind. Mus.*, 36.

SMITH, H. W., (1930) .—"The absorption and excretion of water and salts by marine teleosts". *Amer. J. Physiol.*, 93.

SPOONER, G. M. & H. B. Moore, (1940) .—"The ecology of the Tamar estuary. VI. An account of the macrofauna of the intertidal muds". *J. Mar. Biol. Assoc.*, 24.

USSING, H. H., (1949) .—"Transport of ions across clelular membranes". *Physiol. Rev. Washington*, 29.

VALIKANGAS, I., (1933) .—"Uber die biologie der Ostrea als Brackwassergebiet". *Verh. Ver. Limnologia*, 6.

WEBB, D. A., (1940) .—"Ionic regulation in *Carcinus maenas*". *Proc. Roy. Soc. London*, 129.

3

ESTUARINE PROBLEMS IN SOUTH EAST ASIA

by

J. D. F. Hardenberg**

Estuarine conditions in South East Asia, and probably elsewhere in the world in the tropics, show many interesting features. It is amazing, however, how little attention has been given in literature to these problems in the Indo-Pacific regions, in spite of the fact that in many instances, they maintain very important fisheries.

Estuarine waters, as I define them, are those water masses where mixing of fresh river water and pure sea water takes place. Estuarine conditions are therefore not confined to those areas which we should call an estuary or river mouth when inspecting a map or chart. Estuarine conditions can be found far out at sea, depending on the strength of the out-

*Earlier literature on osmotic regulation has been listed by Dakin (1935) and Krogh (1939).

** Head of the Laboratory for the Investigation of the Sea, Djakarta.

flow of the river, and on the other hand far up the river in some cases, where a casual observer would only be expecting normal river conditions.

The estuarine waters with their own specific peculiarities do not belong to the special interests of the oceanographer, who mostly stops when he enters an area of the sea disturbed by river water. The same holds good for the student of fresh water, though in a reverse way. Perhaps it is herein that we find one of the reasons that estuarine conditions have been neglected for so long. The study of estuarine waters is not merely a study of brackish water, wherein much has been done in other countries. Estuarine water is not always brackish, it may have a salinity of almost as high as so-called pure sea water and on the other hand its salinity may be almost nil.

The formation of estuarine conditions in front of, in and above a river mouth is subject to the influence of the tides. The result of these combined factors is very specific in a hydrological and a zoological meaning. A special estuarine fish fauna for instance has developed, a fish fauna since long known in species but never described as a whole.

Let us consider first in a very general way, the hydrology of the area. Coming in from the open sea we are first struck by the rather rapid discolouration of the blue sea water into greenish and later on into a muddish brownish tinge. This colour is found some distance up the river the water of which becomes brownish when the river is muddy, or, when there is not much silt in suspension, the colour may be tea-brown or even blackish, this being due, in Sumatra and Borneo, to the fact that most of the rivers are the outflow of enormous peat forests. This colour is formed by humic acids and the pH may be even less than five.

The discolouration of the seawater is in the first place due to an increase in the number of plankton organisms. Copepods diminish to be replaced by an increased amount of diatoms and Noctiluca. Open sea species disappear to be replaced by coastal forms. The same holds good of course for the planktonic fish eggs.

The augmented plankton life, mainly diatoms, is the result of an increase in the amount of nutrient salts.

Actual figures in the archives of the Laboratory for Investigation of the Sea were lost during the war, but the amount of phosphate can be 10-12 mgr., a very high figure when compared with figures of the middle of the Java Sea where it was never more than 4-6 mgr.

Salinities of course, become lower and lower nearer to the river mouth proper until several miles or in some cases, several tens of miles upstream the water is entirely fresh. How far salt water is to be found upstream depends on each river system. Some rivers bring down more water than others, and of course the dry and the rainy season have a considerable influence. I know of two rivers next to each other, the Mesudji and the Tulang Bawang in South Sumatra, where the first has salt water up to forty miles upstream and the other only fifteen nautical miles!

Thus far, I have been speaking only of surface salinities; When we take the lower layers into consideration, matters become more interesting and a big difference between tropical and non-tropical rivers shows up in respect of the method of mixing of the waters.

Just in front of the river mouth in tropical countries, we find a bar, the consistency, origin and shape of which will be discussed later.

The hydrography of a river mouth has been extensively studied in the river Tee in the North of England. As could be expected we find vertically different layers of density, each layer of lower density flowing over a layer of higher density in a range from pure river to pure sea water, the whole packet of layers shifting to and fro with the tides. A rather simple condition is maintained all the time.

Conditions in the tropics are not so simple because of the existence of the so called bar. This bar is always horseshoe-shaped with the open side landwards, or perhaps better said, riverwards. This side (the open), is steep, even very steep, and on the other hand we find a very gentle slope in the seaward direction.

Seaward of the highest point of the bar, we find the same phenomena as in the estuary of the Tee, a packet of layers of different density, With the incoming tide, the layer of highest density that can just flow over the bar streams over the steep side as a kind of subaquatic waterfall, thence flowing in some cases many miles over the river bed or river trough.

This water then becomes more or less captured and can be pressed out only partly by the pressure of flow of the river at low tide; the extent of this will, of course, be dependent upon the amount of water which the river carries off. This varies according to the monsoon.

This rather salt water in the river bed has, of course, its influence on the components of the fauna. Many fish normally living in water of a certain salinity are to be found miles upstream in company with others belonging to much lower salinity or even fresh water. The words "in sea and rivers" as found in many handbooks can thus be most deceiving. The fish does not live in the river, in the general

meaning of the word, but only in a salt water layer on the bottom of the river.

The most interesting phenomenon in the river mouth problem, however, is the bar itself. How it came into being, what is the explanation of its peculiar shape, of what material it is built up and why this bar is not eroded away by the often heavy tidal streams are questions to which a satisfactory answer cannot yet be given. The problem is very complex, and chemical and physico chemical factors probably play a very important role in it.

The bar consists of soft to very soft mud. No channel can be traced, at least no channels of importance. In front of the bigger rivers of Sumatra and Borneo the top of the bar is always about 10 feet below low water. In front of smaller rivers the water depth is even much lower, but how far a definite connection exists between the width of the river, the amount of outflow of fresh water and the strength of the tides, I cannot say. This is a big problem in itself and to solve this part alone will probably require team work between several specialists.

As already stated above, many rivers—and especially those which flow through primaeval forests—have relatively little mud in suspension and their water is tea-brown to blackish, a condition due, without doubt, to the enormous peat bogs found in the interior. The river water is more or less a solution of humic acids and carries a great amount of colloidal matter.

As soon as this colloidal matter in suspension is mixed with water of a certain salinity it will coagulate and of course settle down.

I think it is this matter, together with eventual silt which builds up the bar. It seems that as soon as the material is settled the adherence of the particles is very great, since otherwise the heavy tidal streams, in many cases 5 to 6 nautical miles or even more, would sweep all the material away and keep it in suspension until it could settle down again farther out at sea and that this is not so is a plain fact.

However this may be, I can at this moment give no explanation at all of the peculiar formation of the bar, especially of the steep innerside which is always there. One should expect that where there is a bar, this should be of symmetrical shape. At any incoming tide the top of the bar should be removed and swept up into the river proper to fill up, in the long run, the deep river trough. I cannot explain why this does not happen. The difference in depth on the bar and inside the bar can often be 6-7 meter or even more.

Wherever there is a smaller tributary entering the main river within the estuarine area, one will find the same features on a smaller scale. This means since there is never pure seawater there, that even in this area the coagulation is sufficient, or that it is not a chemical (pH) coagulation effect, but something else common to gradient zones of different intensity.

The mud in the area of the bar seems to be very rich in organic matter since many bottom animals, especially Annelids, live in it, forms which I did not find on the normal seabottom, where bottom life is much scarcer.

The estuarine waters teem with fish and plankton life, and for the seas of the Indo-Australian Archipelago are rather rich in phosphates. This phosphate rich water is never carried out far into sea, a distance of about thirty to forty miles being in most cases the limit though the lower salinity can often be traced much farther away. I have often wondered what is happening here for the diatom-belt does not reach farther than the region of high phosphate content. I have never found in the Java Sea a rich diatom plankton with a low phosphate content such as can be found in most temperate waters just after the diatom bloom. I hope to be able in the coming years to tackle this problem and see whether it holds true in all cases. Should it be so then there must be some agent which removes the phosphate after a certain time. This can be either a bloom of nannoplankton which escapes the coarse ordinary plankton net or a chemical reaction, unknown thus far, possibly caused by the high constant temperature in tropical seas. Personally, I think that many unknown factors will be found in these areas. One should bear in mind that the science of the sea has been built up in temperate waters, and I doubt whether everything determined there is validly applicable to the tropics.

The very rich animal life in estuarine areas is a source of potential fisheries and many important centres have arisen in such regions. Two groups are especially important, the Crustaceans and of course the fish.

The Crustaceans again can be divided into two groups, the shrimps, which are found in enormous numbers and the Sergestids. Among the shrimps species of Penaeopsis and Parapenaeopsis are predominant.

Sergestids, which in a biological sense, belong to the plankton, are economically important in the Indonesian area. They are caught in enormous quantities and the so-called terassi, a kind of fish paste, is made of them by fermentation and used as a kind of spice in the various side dishes of the rice diet of the inhabitants.

From an economic as well as from a faunistic and biological standpoint, the group of the fishes is of the greatest importance. The estuarine waters

teem with fish life, as may be judged from the number of planktonic eggs in a single plankton haul.

This rich fish fauna is, for a tropical region, rather poor in species. In the estuary of the Rokan —A Sumatran river following into the Malacca Straits—I counted only 175 species, all occasional guests included. The number of individuals, however, is enormous.

In the estuarine waters which are often muddy and always very rich in plankton, light cannot penetrate very far. It is not surprising, therefore, that its fish fauna show affinities to a deep sea fauna in some of its features. Certain genera belonging to non-related families as the Clupeids and the Polynemids for instance have prolonged fin rays, others have small diminutive eyes. Also, for instance, I have described a blind sole, thus far found only in the estuarine area of the Rokan in Sumatra and of the Kapuas in West Borneo.

More amazing, however, is the fact that there are found species which have their nearest relations in the deep sea, as for instance the so-called Bombay Duck, *Harpodon nehereus* (Ham. Buch.) and there is another one *Bregmaceros macclellandi* (Thomps.) which cannot be distinguished from specimens out of the deep sea itself.

The fish fauna can be divided into 5 different groups in sequence of their importance, ecologically as well as economically:

1. Real estuarine fish.
2. Coastal fish.
3. Anadromous species.
4. Catadromous species.
5. Occasional guests. This last group has, of course, importance only for the ichthyologist.

In the group of the true estuarine species, I include only those species which pass their whole life cycle within the estuarine areas. They form the bulk of the catch of the fishermen; within this group distinctions can be made in species which live farther from or nearer to the river mouth proper, parts therefore with a higher or lower mean salinity. I shall not here go into details since it is an aspect beyond the scope of the paper, and, what is more, the determining factors of these smaller biological units are not quite well known yet. I suspect that next to salinity the degree of muddiness is of some importance, and it may be that the depth is a factor too.

In the western part of the Indo-Australian Archipelago the species composing the group of estuarine fish is everywhere the same. Proportions may perhaps differ in a small scale. Occasionally a species seems to be entirely lacking, as for instance, seems to be the case with *Thryssa kammalensis* (Blkr.) However, one has to be careful with conclusions in this respect, since fishing methods are not the same everywhere.

Clupeiformes, especially the more primitive ones, form the bulk of the catch. I will mention here, only a few of the most important ones.

Chirocentrus hypselosoma (Blkr.) is found regularly. *Setipinna taty* (C.V.) is a key species; it is found more seaward, to be replaced more landward by *Setipinna breviceps* (Cantor). This again by *Setipinna melanochir* (Blkr.) in the river mouth proper or even farther upstream. Generally young and larval specimens are found in water with a much lower salinity than the full grown.

Equal in importance is *Coilia dissumierii* C.V. Other species of this genus live in pure fresh water.

Thryssa kammalensis (Blkr.) can be dominant too in some estuaries, although in others, it is rare or at least seems to be lacking.

Of the genus Stolephorus only *Stolephorus baganensis* Hardenberg seems to be especially confined to these waters.

Of the true Clupeids only *Opisthopterus tartoor* (C.V.) and *Raconda russelliana* Gray are found regularly although never in great numbers.

Equal in abundance in the composition of the catches is *Harpodon nehereus* (Ham. Buch.). Sometimes a large proportion of the catch consists of this species.

Of the Hemirhamphus species, *Hemirhamphus georgii* C.V. must be mentioned here. However, it has no economic importance. The flatfish have two true estuarine forms, viz., *Typhlachirus caecus* Hardenberg, the blind sole mentioned above, and the small *Cynoglossus monopus* (Blkr.), which occur in great numbers.

Kurtus indicus Bloch is a true estuarine form and the same can be said of *Johnius dussumieri* (Cuvier) and of *Stromateus cinereus* Bloch, a species which in the open sea is replaced by *Stromateus niger* Bloch.

Typical are eel-like Gobiids, such as *Gobioides anguillaris* (L.), *G. cirratus* (Blyth.) and *G. rubicendus* (Ham. Buch.) of which the last one is found in much lower salinities than the other two. Tyrpauchen and Trypauchenichthys may be only mentioned here.

Of the group of the Gymnodontes only *Xenopterus naritus* Richardson is common. Among the sharks, only *Carcharias mulleri* Heck is found in great numbers.

Apart from the true estuarine fish, another faunal element is of importance faunistically as well

as economically. This is the group of what I have called the coastal fishes. These species are not restricted to the estuarine areas alone, but are common elsewhere too, where there are no big rivers but at the most small rivulets are found, and provided that the coast and sea bottom are muddy. Coastal species living on coral reefs and rocky shores naturally enough are not found in estuarine conditions. In general this coastal group of fish is found everywhere along the shores of the greater Sunda Islands, except where their coast is expected to the open ocean.

These species belonging to the coastal group do not necessarily spend their whole life cycle in the estuarine area. Young and adult can be found elsewhere, although in some cases, there seems to be an accumulation of juveniles in the river mouth areas.

Among the Clupeiformes Pellona species should be mentioned here, together with *Dorosoma chacunda* (H.B.) and *Megalops cyprinoides* (Brouss.).

Among the Silurids, different species of the genus Arius should especially be noted. *Arius thalassinus* (Rupp.) forms an exception, this species is truly marine. Among the eels it is especially the Muraenesox species which are representative of this coastal group. The same can be stated for *Tylosurus strongylurus* (v. Hass.) and some Hemirhamphus and Zenarchopterus species of lesser faunistic importance.

Eleutheronema tetaradactylum (Shaw) is always found in great numbers. It probably propagates in the estuaries, since young fry are numerous here. Immature and mature individuals, however, are common everywhere along suitable stretches of the coastline.

Several species belonging to different genera of the Sciaenids belong probably to the same biological unit as *E. tetradactylum,* as, for instance *Otolithoides biauritus* (Cantor).

Trichiurus savala C. V. and *Tr. glossodon* Blkr. certainly spawn in estuarine waters or at least in the nearest vicinity in a seaward direction. Young as well as adult specimens are found elsewhere too. *Tr. savala* tolerates water of much lower salinity than *Tr. glossodon.*

Carangids are rare in the estuarine area. Most common are *Megalaspis cordyla* (L.) and *Atropus atropus* (Bl. Schn.). Only small individuals can be caught. Among the Scombroids *Cybium kuhlii* C.V. and *C. guttatum* Bl. Schn. are to be mentioned in this respect.

Sharks are proportionally rare in front of the river mouth with the exception of the already mentioned *Carcharias mulleri.* Among skates and rays I shall mention here only *Trygon walga* Mull.

Among species migrating from fresh water into the tidal area catadromous fish, especially Siluroids, have some, though rather small, importance. Very little is known about their biology.

Pangasius polyuranodon (Blkr.), *P. nasutus* (Blkr.), *Cryptopterus hexapterus* (Blkr.), Ketengus, Hemipimelodus and Macrones species may be mentioned in this respect.

Species migrating the other way round, anadromous fishes, out of the sea into fresh water, are few, although in some places an important form of fishing takes place on them. Only two species have to be mentioned here, the shads *Clupea (Alosa) toli* C.V. and *Clupea (Alosa) macrura* (Blkr.).

I will conclude my paper with a few general remarks. Several bicoenoses can be distinguished within an estuarine area, as I have already hinted above, but they are still imperfectly known to me. Moreover, they are not the same in every river mouth and much, very much, has still to be done here.

In general it can be said that the lower the average salinity in a given area of an estuary, the smaller the individuals even of the true estuarine species. Fry and young specimens are found nearest to the river mouth proper. This holds good for all species, though the area of distribution for different species may overlap each other. The bulk for instance of mature Gobioides is found in the same region as the bulk of the young Stromateus. More instances can be quoted, but I prefer not to do this, as much is still unknown.

The estuarine fauna as sketchily described above is confined to the coasts of South Asia and to the coasts of Sumatra and Borneo, Java shows this fauna much impoverished, since no big rivers are found on this island.

On the south coast of this island there is a region with estuarine conditions large enough to maintain a true estuarine fauna. Of all key species only Eleutheronema, Gobioides and Trypanchen are present, which is very interesting from a zoogeographical standpoint.

There is, however, another region with estuarine conditions quite isolated from South East Asia; this is south New Guinea, separated from the Sunda Islands by the deep Molucca Seas. Here we find an interesting estuarine fauna too, which at first sight is identical with the Asian one but which at closer examination shows to be different, *Coilia dussumierii* seems to be lacking. Of the Setipinna species, only *S. taty* is found, though certainly belonging to a special race or subspecies.

Opisthopterus and Raconda seem to be lacking too, but replaced by species which have the same external appearance. They belong however to another genus, new to science. *Kurtus indicus* is replaced by *Kurtus gulliveri* Casteln. Gobioides species are common, though the species are not always the same as on the Sunda shelf.

Thus far, this estuarine fauna is very imperfectly known and a big source of new things are still open here to the ichthyologist.

I think that an estuarine fauna will be found elsewhere in the tropics on other continents too. Nothing is known hereover thus far. Let us hope that within a short time this will no longer be so.

4

APPLICATION OF THE PRINCIPLES OF FISH CULTURE TO ESTUARINE CONDITIONS IN SINGAPORE

by

D. W. Le Mare*

The term fish-culture in this paper will be confined to the production of fish as a staple human food; the production of fish for sport, aesthetic pursuits or luxuries is outside present consideration. Regarded in this sense then, the principles of fish-culture have implications under two headings, Biological and Economic. They may be enumerated as follows: The first, I consider to be the slogan for fish-culture.

1. Conserve fertility in the pond.
2. Utilise fast growing species.
3. Utilise species which breed readily.
4. Food supplies must be cheap and readily available.
5. Utilise fish which are acceptable to the consumer.
6. Select land which is suitable.

The estuarine conditions with which we are concerned to apply the above principles, are variations in salinity, rise and fall of tide and the supply of nutrient salts from the land mass through which the river runs, the estuary of which is under consideration.

We are all familiar with the pond culture systems of Java and the Philippines for "ikan bandeng" or "bangos" *Chanos chanos;* the traditional methods of fish culture by Chinese pond owners either as pond systems or as part of small holdings are well known; Carp culture in Central Europe and by the Jews in Palestine has been well described, however, in each method there are practical difficulties to be overcome which make their further development costly. In the Chanos cultivation there is the difficulty of maintaining a high yield of fish to the acre, year after year, for while the fish is fast growing when adequate crops of the algae on which it feeds are available; after a number of fish harvests the yield to the acre is known to drop. *Chanos chanos* is a selective feeder, and unless its specific diet is available it will not thrive. For the Chinese pond systems, the yield is maintained perennially by both intensive fertilisation of the ponds with pig-dung or nightsoil and by feeding the fish with vegetable crops, grass, tapioca leaves, yam leaves, etc. the former must be purchased and the latter demand that land additional to the land occupied by the pond be put under cultivation. This demands both man-power and additional agricultural fertilizer, consequently the real yield of fish per acre as practised by the Chinese in their carp culture in Singapore, for instance. should take into account the land utilised for growing the food crops. The same arguments apply to the pond culture methods adopted in Europe, where, for instance municipal sewage is used, as in Munich, involving transport charges and in the use of soya beans or lupins requiring farms.

The most important substances which must be conserved are lime, phosphorous, potassium, and nitrogen, and, although we know comparatively little about their influence as yet, certain elements in minimal or trace quantities, e.g. copper, strontium. In all known methods of fish-culture, the importance of lime lies in its ability to change certain properties of bottom soils and to act as a buffer in the presence of all acids. Categorically it can be said that a weekly alkaline reaction has been found most productive in fish ponds and that very acid waters are undesirable. Apart from a direct effect on fish, acidity impedes the recirculation of nutrients by reducing the rate of decomposition and by inhibiting nitrogen fixation.

* Director of Fisheries, Federation of Malaya and Singapore.

The calcium in lime will displace certain other fertilizing substances from organic colloidal solution consequently making them more readily available, e.g. Potassium, and phosphate. Because of its acid buffering capacity, lime increases the ability of water to hold carbon dioxide thus aiding the respiration of the aquatic flora. Calcium is essential for the growth of bone and while a necessary minimum concentration is essential the impedence of growth of fish in relation to calcium lack is not, so far as I am aware, fully determined. The Chinese use lime as a disinfectant to kill harmful parasites and predators, quicklime, being dug into the bottom of a pond when it is being prepared for stocking. The subsequent utilisation of the slaked lime in the pond is of particular importance in the bottom soil.

Potassium; optimum concentrations of this element are unknown. However, it is readily absorbed by plant tissues and is particularly effective in stimulating the growth of aquatic flora. During rapid plant growth, potassium from the water and soil is stored in the tissues to be released later when the flora dies and decomposes and is held in the bottom soil to be released later at another season. Often the results from potassium appear to be erratic and characterized by peculiarities which are not well understood. When potassium is able to improve the growth of carp, young fish respond much more readily than do older fish. It may be that one of the effects of potassium is indirect, in that it assists the formation of available phosphate salts through releasing dilute acid.

Phosphorous is the most important elemental fertilizer. It is probably a limiting factor in the harvest or yield cycle; its importance in the periodical and seasonal plankton blooming is well described by Pearsall, Harvey and others. The use of phosphate in ponds is followed by increased yields. It is well known that natural phosphate concentration is higher near the bottom, this is largely due to local acidity, arising from decomposition of organic materials, in the water just above the bottom. Nitrogen is perhaps the most elusive of essential fertilizers. In general, the assimilation of nitrogen by the fish may be said to be but one link in a cycle of chemical transformations, in which bacteria play a larger part. It must be remembered that the surface of the pond is perpetually in contact with an unlimited supply of this element. Therefore, as well as the addition of nitrogen from extraneous fertilizers, there is some degree of nitrogen fixation by both bacteria and algae, as demonstrated by *De 1939* and *Fogg 1942* for certain genera of Cyanophycea. The amount fixed is certainly significant, but whether a fish pond could be designed, with suitably controlled and cultured bacteria and algae to provide the system with all the nitrogen required is as yet undetermined. Nitrogen is essential to the formation of fish as protein; and the whole subject of the utilization of nitrogen, its conservation and conversion is a vast and important field for further research. Moreover, the importance of and objections to inorganic nitrogen fertilizers are not yet clarified.

An important aspect to be considered is the relation of nitrogen and carbon concentrations. If we consider that fixation of atmospheric nitrogen will provide a significant quantity of nitrogen to a pond, then too the value of added organic fertilizers, such as compost, nightsoil, cow or horse manure or municipal sewage also achieve special importance by virtue of their carbohydrate content. Nitrogen fixation by bacteria must proceed in a substrate of carbohydrate materials essential both as a source of energy, to anaerobic forms and as a constituent of bacterial protoplasm in the experimental ponds later to be described, this principle of the importance of nitrogen-carbon ratio to the formation of fish protoplasm will readily be appreciated.

Having enlarged at some length on the first principle or slogan for the fish culturist, the practical and theoretical implications of the other principles will now be considered.

A fast growing species or communities of species is most desirable for economic production. While it is possible to utilize slow growing species and to arrange a series of ponds with harvesting arranged in cycle they will, however, yield a low figure per annum per acre and while semi-luxury varieties may provide the fish culturist with a good cash-crop, they do not provide a staple protein for the majority of the population. It is, however, possible to combine both types in one pond with success, but only when the staple-species breeds readily so that the culls of the staple-species when harvested are easily replaced. In general terms it is a principle that only species which breed readily, and the fry of which may easily be obtained should be utilized. While the now traditional sea transport of carp fry from the West river near Canton as far as Malaya and Sarawak has been successfully achieved and of recent years has provided us with a nice experimental problem in bringing them by air, this has only been rendered possible because economically the fish have a semi luxury appeal for festive occasions and at the time of the Chinese New-Year celebrations. The taking of the fry of *Chanos chanos* at certain seasons of the year in restricted areas on the Java coast and their subsequent transport by sea or rail has been economically possible only when labour and transport services have been cheap and the potential purchasing power of the consumer relatively high. Unless the fry can be reared on or very close to the site of the

fish-culture, the additional transport charges with handling, render the final product too expensive as a staple.

The supply of food must also be easily obtained preferably as a catch crop to a major crop or as a by-product of a major manufacturing process, e.g. tapioca leaves, soya bean cake or rice bran. The biological implications of the feeding are both directly connected with the manuring of ponds and conservation of fertility and with the conversion factor of fish protein. It is important to select not only fish-food which can easily be produced but which will give a high conversion factor for quantity of food administered to the fish when related to yield. The carbon-nitrogen-phosphorous-ratio is important in this respect, and legumes are satisfactory in providing this.

The human factor when considered from the point of view of consumer preference is of the utmost importance. While as biologist and economist the fisheries worker may be able to produce a high yield of fish at low cost he must consider the palate of the consumer markets. It is almost a dogma that the less experienced and educated human beings are the more conservative they are in their feeding habits. Therefore, in putting a new fish before the public as a staple, it is essential that it should be acceptable; a little propaganda work properly adapted to the mental outlook of the potential consumer may not be amiss.

Finally sites should be selected which will fulfil certain physical as well as biological conditions. The substratum should be of mud or clay which will hold water, sand or gravel is quite unsatisfactory. Water supply should at least be adequate to replace loss by both evaporation and seepage; topographically the site should be not subjected to flooding yet at the same time should be of sufficient gradient to permit adequate draining of the ponds, for it may be necessary for a variety of reasons other than for harvesting to be able to drain the ponds empty. As our Dutch friends found at one stage in their work on *Chanos chanos* it became essential to drain the ponds as a step in Malaria-control, and I mention in passing that the development of fish-culture poses a number of problems relating to water-borne disease, malaria, filariasis and both Nematode and Platyhelminth worms. Consequently the closest relations should be maintained with the health authorities for while improving nutritional standards we must not increase the risk of the incidence of disease.

Having enunciated in general terms the major principles governing fish-culture, I will describe their successful appplication to the rearing of a specific fish in estuarine conditions in Singapore and attempt to draw some significant biological conclusions.

The fish concerned was a Cichlid, *Tilapia mossambica*. This species is indigeneous to East Africa. Its advent to South-East Asia and specifically to Singapore during the occupation by the Japanese is a separate story. Suffice it that when we returned to Singapore after the war this fish was established in one or two fresh-water ponds. Now Singapore is a small island with a high population of mixed races nearly all of whom eat fish. Due to development it is now land-hungry and both for agricultural or piscicultural purposes and for houses, land is hard to come by. Therefore in 1947 an attempt was made to investigate the potentialities of developing fish ponds in the marginal mangrove swamp at the west-end of the island with the main object of studying mullet and prawn development, incidental to the mullet and by accident, some Tilapia were admitted. It was soon found that this species thrived and specific experiments were started to study its cultural possibilities.

The site was selected in an area of cleared mangrove swamp on the bank of a small tidal river about one quarter of a mile from the sea. An area of pond was cleared and the spoil used for making the bunds, the substratum was a steely-blue clay and held water well. A sluice gate was built at the river-side so that the pond could be filled at high tide and drained at low tide. The maximum depth of the pond was four feet six inches. A third class road ran along one side. The area was only subjected to possible flooding at the equinoctial tides and adequate bunding could prevent this. The river itself drained a semi agricultural suburb of the town of Singapore. The Malay people who live in this area are the descendants of the original inhabitants of Singapore and are accustomed to building their houses on poles over the water. Eight Malay houses of this type were included in the one and one-quarter acre pond. This leads us on to the question of pond fertility as related to the species *Tilapia mossambica*. All the inhabitants of the houses were encouraged to throw their household waste into the pond, particularly scraps from the kitchen. Now this meant that a general composting of the pond was effected. Tilapia is omnivorous, with a selective preference for planktonic crustaceans.* The pond was filled at a high spring tide in February and the Tilapia at approximately 5 cm were introduced. The salinity of the water was 22 parts per thousand, the subsequent maintenance of the pond involved opening up the sluice gate at high spring tide every mouth to top up losses by evaporation and seepage. Rain and the river

* Under other conditions Tilapia has been shown to have a selective preference for certain Algae.

maintained the salinity ± 2, of 20 parts per thousand salinity. With the initial flooding of the pond larval Peneids and particularly larval Acetes in quantities were introduced. These thrived particularly as a result of the household waste which was composting the pond and they in their turn formed a high proportion of the Tilapia food. By maintaining the pond stagnant, apart from the monthly topping up, the fertility was conserved and the phytoplankton bloomed providing adequate food for the young Crustacean forms. The monthly inlet of water moreover stirred up the bottom and doubtless helped to revive the distribution of phosphate which, while the pond was lying still in the interim periods would be building up on or near the bottom. The Tilapia grew rapidly and at the end of an eight month period the population when analysed for all specimens above 10 cm in length showed a bi-modal distribution for numbers plotted against length. The largest fish were 36 cm in length. There were a large number of fish under 10 cm., however, it was clear that breeding had taken place at least twice. One primary breeding when the initial stock reached sexual maturity which was evidenced in the clear bi-modal curve. Thereafter it would appear that breeding became promiscuous between different generations for the remainder showed various peaks, which were not analysable simply. However, the second and third principles which I enunciated were clearly satisfied, for the fish which were first introduced grew from a length of 5 cm. in eight months and breeding actually occurred in the pond where culture was being effected. The food supplies were readily available and cost nothing. The fish is extremely hardy and appealed to the Indian people of whom the Tamils form quite a high percentage in Malaya because it could be offered for sale alive in tubs in the market. It has been accepted by the Malays readily. Perhaps this is in part due to the advice of an elder—the State Secretary of Pahang—who on hearing that the fish came from Africa suggested that it be named Ikan Nile after the river Nile, Father of all waters. In addition to the Tilapia which showed a yield at the rate of 1,300 lbs. to the acre per annum, there was an incidental catch of prawns, mullet and other small mixed fish. This experiment has been caried out two years in succession and the principle is now being propagated in Malaya as a whole.

The conclusions to be drawn from this, are that by selecting marginal land in an estuary and putting it under fish culture it was turned from waste land to being profitable and productive. That by selection of *Tilapia mossambica*, an omnivorous euryhaline species rapid growth was achieved, at no cost. The facultative tolerance to variations in salinity is probably of great physiological importance. Undoubtedly the fish grows much more rapidly and to a larger size in the brackish water than in fresh water and I believe that this is largely due to the fact that if a fish is in an isotonic solution there will be no utilization of food materials and subsequent expenditure of energy on osmoregulation. With the run off from the land into the river there will be a number of elements brought down in trace quantities and the fish probably benefit from this. The maintenance of the pond is minimal and there is no need for either imported food or fertilizer. The real yield is of the order of 1,500 lbs. of protein to the acre per annum, at no cost other than capital outlay and maintenance and there is no foreseeable reason why it should not be perpetual.

REFERENCES

SCHAEPERCLAUS, W., (1933) .—Textbook of Pond Culture.

DE, P. K., (1939) .—The role of blue-green algae in nitrogen fixation in rice fields. *Proc. Roy. Soc. London*, B. (1939) : 121-139.

FOGGS, G. E., (1942) .—Studies on nitrogen fixation by blue-green algae. *Journ. Exp. Biol.* 78-87.

NEESS, J. C., (1949) .—Development & Status of pond fertilization in Central Europe.

LE MARE, D. W., (1947) .—Annual Report of the Fisheries Department. Federation of Malaya and Singapore.

LE MARE, D. W., (1948) .—Annual Reprot of the Fisheries Department, Federation of Malaya and Singapore.

5

PRELIMINARY OBSERVATIONS UPON THE RELEASE OF PHOSPHATE FROM ESTUARINE MUD.

by

W. Stephenson*

Abstract

A study has been made of the changes which occur in estuarine muds held in the laboratory. The release and absorption of phosphates by these muds in the presence of organisms has been studied and the muds tested have been taken both from surface and sub-surface layers. Oxygen requirements have also been considered.

I. INTRODUCTION

The significance of the phosphate concentrations of sea water in assessing marine productivity is too well known to need further emphasis in this paper. There is little information, however, on the role of bottom deposits and suspended particles in relation to the phosphate in sea water. Rivers must remove phosphate from the land, as McHargue & Peters demonstrated in 1921. It is less certain whether this mainly accumulates near the river mouth as Atkins (1926) suggested, or whether it mainly enriches the sea beyond the estuary (Lucas, 1929; Riley, 1937; Kalle, 1937; Graham, 1938; Graham & Harding, 1938; and Hickling, 1938). This problem has an economic significance in the Indo-Pacific region, where estuarine fisheries are important.

Field studies, like those in Chesapeake Bay by Newcombe & Lang (1939); Newcombe, Home, & Shepherd (1939) and Newcombe & Brust (1940), are an important approach to this problem, but results are difficult to interpret because numerous significant variables may alter simultaneously and uncontrollably. For example, in Chesapeake Bay, phosphate values were highest in summer; this was attributed to high turbidities reducing illumination and photosynthetic activity, but the suspended material may release phosphate to the water, or the increased phosphate may be related to the reduced oxygen concentration which was demonstrated.

To minimise interpretation difficulties the present investigation was performed under laboratory conditions, at the Dove Marine Laboratory, Cullercoats, University of Durham, England.

II. METHODS

Mud. Details of the samples are given in the appropriate part of the text. All were added to sea water (from the tanks of the Dove Marine Laboratory) contained in greenish glass vessels, 35 x 27 x 35 cm., and kept in a shaded corner of the laboratory. Sufficient mud was added to make a layer approximately 1 cm. thick, although in some experiments layers only 7 mm. thick were used. Unless otherwise stated, tanks were covered with glass plates.

Phosphate determinations were made on the supernatant sea water thereby (a) avoiding the difficulties of determination upon the mud itself, (b) avoiding mechanical disturbance of the mud, (c) obtaining a large proportional change in sea water composition for a small change in mud composition. Atkins (1923) original method was used with slight modification (Stephenson, 1949). Concentrations are expressed as milligrams P_2O_5 per cubic metre, and in general were accurate to about $\pm$ 2% though when large amounts of ferric iron were present, inaccuracies were probably higher.

Filtration. With turbid liquids, filtration was necessary. Samples were filtered through Whatman No. 542 paper, the first 20 ml. discarded, and the remainder collected into a vessel containing 2 ml. of 40% formalin per 100 ml. of filtrate. The reasons for this procedure have been described (Stephenson, 1949).

Ferric iron determination were made as follows (modified from Ellis et al., 1946):— to 85 ml. of sea water were added 5 ml. concentrated H_2SO_4 and 10 ml. of 12% potassium thiocyanate. The colour developing in 8-10 min. was compared with that of the nearest of three standards. No corrections were made for salt errors, and the method, though crude, (Thompson, Bremner & Jamieson, 1932) was adequate for the present purposes. Concentrations are expressed as milligrams of Fe per cubic metre and are accurate under the special conditions of the experiment to about $\pm$ 15%.

Oxygen determinations were made by the Winkler method with preliminary oxidation. Considerable addition of $KMnO_4$ solution were required and this was made up in 1.5% Nacl solution to prevent it from rising in the bottle and being lost on re-insertion of the stopper.

* Professor of Zoology, University of Queensland, BRISBANE.

pH determinations were made colorimetrically and are accurate to about 0.05.

III. GENERAL OBSERVATIONS ON MUD KEPT IN AQUARIA

Under the described conditions, there are noteable changes in the system, mostly caused by the mud organisms. Initially, the water is turbid and remains so for about three days. The mud population meanwhile regains its initial spatial relationships the animals displaced to deeper layers migrating to the surface, while burrowing organisms reform their burrows. This period of "settling down" is followed by a period of approximately "normal" conditions, which ends in one of two ways. Using sandier muds, the surfaces of the glass tanks are colonised by diatoms or Enteromorpha, and the tank becomes a green walled pool. This period of "photosynthetic excess" develops in about two months in the (temperate) winter and in about half this time in summer. With black or dark brown muds, the "normal" period often only lasts for two days, and is followed by a period of reduced oxygen concentration of the supernatant sea water. The microfauna migrates from the mud into the liquid, sulphuretted hydrogen is evolved, and the fauna dies.

IV. EXPERIMENTS WITH SANDY MUD

Samples were collected from the top centimetre of mud at mid-tide level on the South bank of the River Blyth (Northumberland). Grit was removed before addition to the tanks.

TABLE 1.

A.

11th Dec., 1946; mud collected c.10.00 hrs. G.M.T.; P_2O_5 sea water from tanks 67 mgm./m³ at 11.30 hrs. Determinations below between 11.00 and 11.30 hrs. G.M.T.

Date (Dec. 1946)	P_2O_5 Aquarium with mud	P_2O_5
17	115	68
18	104	63
19	115	69
20	114	66

B.

11th Feb., 1947, mud collected c. 14.00 hrs. G.M.T.; P_2O_5 sea water from tanks 72 mgm./m³ at 16.45 hrs., mud divided equally by washings between three tanks. Determinations below made daily at this time.

Date	P_2O_5 Mud, in light	P_2O_5 Mud, in dark room	P_2O_5 Control, without mud, in light
19	22, 27	29	70
20	28, 28	34	72
21	29, 27	34	71

Typical results from two samples from apparently identical situations are given in Table 1, and show that (a) estuarine muds may absorb or release phosphate and (b) absorption occurs in darkness to practically the same extent as in light, i.e. that it is largely independent of photosynthetic activity.

The microfauna, principally *Corophium volutator* (Pallas), was removed from the second sample with the grit, and was added later in numbers approximating to its density in nature to one tank and the experiment continued. The results (Table 2) show that phosphate absorption by the second sample was not due to the absence of Corophium, since when they are added, even more phosphate is absorbed.

TABLE 2.

C.

Experiment B continued. 21st. Feb., 1947, 100 *Corophium* added to first illuminated tank with mud.

Date (Feb. 1947)	P_2O_5 Mud, light Corophium	Mud, light	Mud, dark	Control, light no mud
22	31	36	43	72
25	12	30	42	75
26	10	28	40	72

The first and second samples may have differed in that between their collection, the estuary was scoured by a minor flood and the flocculent surface layers may have been removed. Experiments on surface layers were meanwhile undertaken on samples from a different situation.

V. EXPERIMENTS WITH BLACK OR DARK BROWN MUD

Samples were collected from a sheltered side creek (Willington Gut) of the polluted Tyne estuary. Surface samples were scraped from the top 3 mm. and consisted of brown flocculent material with black mud beneath. They contained juvenile annelids [*Capitella capitata* (Fabricus)], nematodes (Theristus spp.,), a copepod (Mesochra sp.), at least 15 genera of ciliates, and diatoms. The subsurface samples were cores 10 cm. deep, taken in the areas from which surface layers were removed. They were black, smelt of sulphuretted hydrogen, and contained no animals or green plants. Both surface and subsurface samples were collected from stations approximately 100 m. apart at the upper, middle and lower reaches of the creek, each at a level of L.W.N. The samples from the upper reach contained a little sand, but the others were soft mud mined with occasional clinkers which were removed when the mud was added to the tanks.

TABLE 3.

1st. Feb., 1947. P_2O_5 tank sea water before addition mud 69 mgm./m³. On starred days samples filtered.

Date (Feb. 1947)	P_2O_5 Upper creek		Middle creek		Lower creek	
	Surface	Subsurface	Surface	Subsurface	Surface	Subsurface
1	177	37	260	254	177	175
2	99	50	134	202	387	259
3	49	47	520	152	850	213
4	237	35	1550	372	1880	323
5	640	39	3480	318	3200	281
6	1180	37	7100	395	5330	299
7	2160	36	13300	280	9150	154
8	4210	To another experiment	18300	To another experiment	12500	140
10	7700		18200		16700	122
13	20500		37200		27100	103

The results obtained (Table 3) show that:— (a) the surface samples released large quantities of phosphate, (b) the deeper samples either absorbed or released phosphate, (c) deeper samples never released as much phosphate as the surface samples, (d) softest muds with least sand gave off most phosphate.

The surface and subsurface samples differed in many ways. There was no microfauna in the latter (apart from ciliates etc. added with the sea water) and its effects were further investigated. Two subsurface samples (Table 3) were pooled, divided between four smaller tanks, and sea water added. One tank was kept as control while elements of the microfauna were inoculated into the remainder (details in Table 4). Phosphate and iron concentrations, and pH values were measured daily, and the

TABLE 4.

Tanks set up 7th Feb., 1947. Next day 15 ml. additions as follows:- tank P—nothing (control); tank Q—Capitella and nematodes with adherent mud; tank R—mud containing very dense nematode population; but without Capitella; tank S—mud without Capitella or nematodes but with dense ciliate population.

Date (Feb. 1947)	Tank P			Tank Q			Tank R			Tank S		
	P_2O_5	Fe	pH	P_2O_5	Fe	pH	P_2O_5	Fe	pH	P_2O_5	Fe	pH
8 (before addition fauna)	41			41			56			41		
10	38	164	7.5	140	385	7.3	358	387	7.4	238	408	7.2
12	51	60	7.45	208	463	7.1	342	168	7.4	148	94	7.3
14	46	108	7.4	210	400	7.2	243	200	7.4	134	140	7.4
16	65	64	7.7	297	455	7.1	254	128	7.5	117	81	7.4
18	74	138	7.7	252	559	7.1	338	218	7.5	342	207	7.6
20	84	76	7.75	258	612	7.15	283	132	7.7	140	176	7.55

results (Table 4) show that the microfauna releases phosphate, iron, and hydrogen ions from the mud. The phosphate and iron values were very variable, and in similar experiments, erratic results were obtained in successive determinations. The iron concentrations greatly exceed normal values for sea water, which in turn exceed the solubility product (Cooper, 1937, 1948). With such large amounts of iron and phosphate mutual interference must occur and both will be present in colloidal and possibly particulate form. Crude observations suggested that particulate material was present. In all tanks the mud surface was rust coloured, and those with added microfauna, the water had a noticeable brown opalescence. Previous work had indicated the difficulties of evaluating the effects of colloids (Stephen-1949), and further investigation of the present unusual conditions was not attempted.

VI. RELEASE OF PHOSPHATE FROM POLLUTED MUDS UNDER DE-OXYGENATED CONDITITIONS

Large surface and subsurface samples from the lower part of the creek (see fig. 1) were each subdivided into three. One pair of subsamples was aerated continuously with large bubbles, one pair kept lightly covered in the usual way, and the third covered with 2 cm. of liquid paraffin to minimise oxygen entry. Phosphate determinations were made daily and results are given in Table 5. These re-emphasise the differences between surface and subsurface samples, and show that phosphate release also depends upon the degree of stagnation.

During this experiment, and those recorded in Table 3, oxygen concentrations were determined for two days (5th and 6th Feb.) in the period when phosphate release was commencing. The results are given on Figure 1 where approximate rates of phosphate release are plotted against oxygen concentrations. This figure shows that when the oxygen concentration of the water is less than about 0.7 mgm. per litre, phosphate comes rapidly from the mud. This effect was so spectacular, compared with the others, that subsequent work has concentrated upon this aspect.

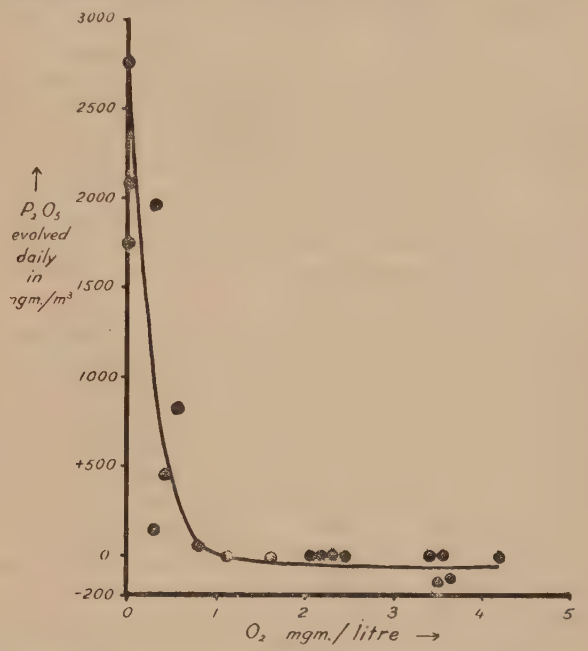


Figure 1. Estimated rate of release of phosphate from polluted mud in terms of milligrams per cubic metre per day against oxygen concentration of the supernatant sea water in milligrams per litre.

TABLE 5.

1st Feb., 1947, P_2O_5 tank sea water before addition mud 69 mgm./m³. On starred days, samples filtered.

Date (Feb. 1947)	Surface samples, P_2O_5 values			Deep samples, P_2O_5 values		
	Aerated	Control	Paraffin	Aerated	Control	Paraffin
1	58	177	150	42	175	164
2	159	387	512	39	259	304
3	607	850	905	42	213	373
4	1380	1880	2230	39	323	267
5	1310	3200	3640	36	281	310
6	1100	5330	5720	66	299	360
7	990	9150	9050	66	154	780
8	840	12500	12500	32	140	1420
10	280	16700	11300	56	122	2960
13	256	27100	20400	45	103	3330

VII. DISCUSSION

The present experiments raise many questions and indicate the complexity of the problem. For example, apparently identical samples from the same situation sometimes release and sometimes absorb phosphates. This may be due to different amounts

of floccular surface material being present and it has been shown that top scrapings release more phosphate than do deeper layers.

It is also unwise to generalise on the effects of the mud fauna. In one case, addition of animals (Corophium) caused a deposit which had absorbed phosphate to absorb even more. In another case addition of microfauna caused release of phosphate (and iron) from mud. These differences may be because the burrows of Corophium oxygenate subsurface layers while the microfauna was causing chemical reduction of a thin surface layer. This would agree with work of Einsele (1938) and Mortimer (1941, 1942) who stress the importance of the state of oxidation or reduction of this layer in fresh water conditions. Before the suggestion can be substantiated, determinations must be made of the oxidation-reduction potentials of the different microhabitats.

Phosphate is released rapidly from polluted mud when the oxygen content of the supernatant liquid is reduced. This might explain the higher summer phosphate figures obtained by Newcombe and his collaborators as previously quoted. Mortimer (1941, 1942) has explained the release of phosphate from fresh water deposits under these conditions in terms of reduction of ferric iron in the surface layers to ferrous iron. In the present conditions, low oxygen concentrations and release of phosphate were accompanied by catastrophic faunistic changes, and eventually the entire fauna was killed. Other experiments have shown that death and enzymatic autolysis of many tissues from marine animals leads to rapid phosphate release and the wholesale destruction of an abundant microfauna must contribute phosphate. Bacterial protoplasm is rich in phosphorus (Renn, 1937), and bacteria occur in immense numbers in superficial layers of marine muds (Zobell, 1946). An investigation of the mortality of these bacteria as the conditions change from oxidising to reducing, would be of great interest.

Phosphate is rapidly released from polluted muds, when the oxygen concentration reaches a low and critical value. Additional parameters of the state of oxidation and reduction of the medium are required, and here again determinations of oxidation-reduction potentials are desirable. Further work was concentrated upon this aspect, and will be published in due course.

VIII. SUMMARY

(1) When estuarine muds are kept in sea water in the laboratory, the organisms present cause marked and uncontrollable changes in conditions.

(2) Phosphates are sometimes released by, and sometimes absorbed by similar samples of muds in the laboratory.

(3) The presence of animals sometimes increases absorption and sometimes initiates evolution of phosphate.

(4) Superficial deposits from a polluted estuary can release large amounts of phosphate; subsurface layers may absorb or evolve phosphate.

(5) Phosphate is given off rapidly from surface layers of mud when the supernatant water becomes de-oxygenated. This may be partially due to catastrophic biological changes.

(6) Future work upon oxidation-reduction potentials of marine deposits is indicated.

I am deeply grateful to Dr. M. C. Bleakly for invaluable assistance in correcting the manuscripts.

REFERENCES

ATKINS, W. R. H., (1923 .—The phosphate content of fresh and salt waters in its relationship to the growth of algal plankton. *J. Mar. Biol. Assoc. U.K.*, N.S., *13*: 119-50.

ATKINS, W. R. H., (1926) .—The phosphate content of fresh and salt waters in its relationship to the growth of algal plankton. Pt. III. *J. Mar. Biol. U.K.*, N.S., *14*: 447-67.

COOPER, L. H. N., (1937) .—Some conditions governing the solubility of iron. *Proc. Roy. Soc., B.*, 124: 299-307.

COOPER, L. H. N., (1948) .—The Distribution of iron in the Waters of the Western English Channel. *J. Mar. Biol. Assoc., U.K.*, N.S., *27*:279-313.

EINSELE, W., (1938) .—Uber chemische and kolloidchemische Vorgange in Elsen-phosphatsystemen unter limnochemischen und limnologischen Gesichtspunken. *Rrch. Hydrobiol. Plankt. 33*: 361-87.

ELLIS, M. M., B. A. WESTFALL, & M. D. ELLIS, (1946) .—Determination of Water Quality. *U.S. Dept. Int. Fish. Wildlife Serv. Res. Dept.* 9.

GRAHAM, M., (1938) .—Phytoplankton and the Herring. Pt. III. Distribution of Phosphate in 1934-1936. *Min. Agric.* Fish., *Fish. Invest.*, Ser. III, *26*, (3), 1-26.

GRAHAM, M. & J. P. Harding, (1938) .—Some observations of the Hydrology and Plankton of the North Sea and English Channel. *J. Mar. Biol. Assoc. U.K.*, N.S., *23*: 301-6.

HICKLING, C. F., (1936) .—The distribution of phosphates in the South Western Area in April, 1938. *J. Mar. Biol. Assoc., U.K.*, N.S., *23*: 197-200.

KALI, K., (1937) .—Nahrstoff-untersuchungen als hydrographisches Hilfsmittel USW. *Ann. d. Hydr. 65 Jahrg.*, (Quoted from Hickling, loc. cit.).

LUCAS, C. C., (1929) .—Further oceanographic studies on the adjacent to the Fraser River Mouth. *Trans. Roy. Soc. Canada.* 3rd Ser., Sect. 5, *23*: 29-58.

MORTIMER, C. H., (1941) .—The Exchange of Dissolved substances between mud and water in lakes. Sections 1, II. *J. Ecology, 29*: 280-229.

MORTIMER, C. H., (1942) .—The Exchange of Dissloved substances between mud and water in lakes. Sections III, IV. *J. Ecology 30*, 147-201.

NEWCOMBE, C. L. & H. F. Brust, (1940) .—Variations in the phosphorus content of estuarine waters of the hesapeake Bay near Solomon's Island, Maryland. *J. Mar. Res., 3*: 76-88.

NEWCOMBE, C. L., W. A. Horne, & B. B. Shepherd, (1939) .—Studies on the Physics and Chemistry of the Estuarine Waters in Chesapeake Bay. *J. Mar. Res. 2*: 87-116.

NEWCOMBE, C. L. & A. G. Lang, (1939) .—The distribution of phosphates in the Chesapeake Bay. *Proc. Amer. Phil. Soc. 81*: 393-410.

RENN, C. E., (1937) .—Bacteria and the phosphorus cycle in the sea. *Biol. Bull. Woods Hole, 72*: 190-5.

RILEY, G. A., (1937) .—The significance of the Mississippi River drainage for Biological Conditions in the Northern Gulf of Mexico. *J. Mar. Res. 1*: 60-74.

STEPHENSON, W., (1946) .—Certain effects of agitation upon the release of phosphate from mud. *J. Mar. Biol. Assoc. U.K.*, N.S., *28*: 371-80.

ZOBELL, C. E., (1946) .—Marine Microbiology. Waltham, Mass. 240 pp.

THOMPSON, T. G., R. W. Bremner, & I. M. Jamiesonfi, (1932) .—Occurence and Determination of Iron in the Sea Water. *Ind. Eng. Chem. (Anal.) 4*: 288-90.

NOTE TO AUTHORS OF PAPERS TO BE PUBLISHED BY THE COUNCIL.

Papers of any length may be submitted but the Executive Committee may be obliged to propose abridgement of papers which exceed in length ten pages of the Council's Proceedings.

Papers may be written in English or French.

Preparation of Manuscript.

Typing. Manuscripts should be typewritten in double spacing with ample margin and on only one side of the paper. Pages should be consecutively numbered in the upper right-hand corner. The original and one carbon should be submitted and the author is advised to retain one carbon. Underlining should be used only where it is intended that the printer should use italic type.

Title. Should be made as brief as possible. Sub-titles should be provided.

Introduction, summary and abstract. It is recommended that the purpose and scope of the paper should be succintly stated in an introductory paragraph; and that the contents of the paper should be indicated by a summary at the end. The summary is not to be confused with the statement of conclusions, which, if required, must be a separate section. An abstract for distribution to abstracting journals must be furnished with the MS.

Footnotes. These should be kept to a minimum and should not be used for citing references. Wherever possible material originally intended for footnotes should be incorporated into the text. Footnotes should be consecutively numbered and indicated by superior numbers; in typing, the footnote should be included in the body of the text, immediately below the line carrying the indication and separated from the text proper by lines above and below it.

References. These should be listed alphabetically and chronologically at the end of the paper. Citations should be made by author, date and, where appropriate, page; the citation of a particular page or figure which may be done in the body of the text, should not be repeated in the list of references where the information furnished should deal with the reference in its entirety. The form of the reference list should be in the following pattern.

DAY. F., (1873).—Report on the Freshwater fish and fisheries of India and Burma. Calcutta: Govt: Printer.

— (1876a).—Introduction of Trout and Tench into India. Linn. Soc. Lond., *Journ.*, 12: 562-565.

— (1876b).—On the Fishes of Yarkand. Zool. Soc. Lond., *Proc.*, (1876): 781-807.

The main points in this system are as follows:—

Name:—Surname is given in capital. Only initials are given for personal names and these follow the surname except for multiple authorship in which case initials of second and other authors precede the surname; prefixes ('van' etc.) are treated as being part of the initials but are not abbreviated and are in small type. In double authorship an ampersand stands between the two sets of initials; in treble and other authorship a comma stands between the two sets of initials and after the second and other surname where there are more than three authors; but an ampersand follows the penultimate surname. A comma stands at the end of the set of names. Where papers by the same author follow one another the repeated name is represented by a dash.

Date:—The date of publication is given in brackets after the name and is followed by a period and a dash.

Title:—Is quoted as published except where papers in a series under a general title follow one another, in which case the general title is represented by the word 'ibid'.

Publication:—For books, the publishers' name and the city where published. For periodicals the title of the periodical is abbreviated in accordance with the system of the "World List of Scientific Periodicals". Only arabic numbers are used for volume, and page numbers except where interpolated series of pages bearing Roman numbers are to be cited in addition to the main series. Where volumes are identified by the year number, as in the case of the proceedings of certain societies, this is given in brackets as the first number; part numbers are given in brackets, only when each part carries separate pagination; the volume number (and part number when present) is followed by a colon and the page numbers. If the periodical has appeared in more than one series, this must be indicated by the abbreviation 'Ser.' followed by the number and a comma, to precede the volume number.

Text. Whilst the author may follow whatever standard dictionary practice he may choose, it is important that the text should be consistent throughout in its spelling, and in its method of capitalization, abbreviation, compounding etc. Wherever numbers are adjectival in function they should be written in full, otherwise, unless the number is less than ten, they should be given in arabic figures. Numbers of course may not be used for beginning a sentence. Whenever possible the use of personal titles should be avoided in referring to person's work, published papers or opinions. Scientific Names: Italics may be used only for a full binomial or trinomial citation; they may not be used for a generic name standing alone, nor for names of groups higher than genera. Vernacular names: these are not to be given in italics. It is hoped to be able to establish some standard practice in respect of the usage of certain words such as shoals (schools), and certain plurals such as fish (fishes), squid (squids).

Paragraphs of excessive length are to be avoided.

Legends and Tables. These should be typed separately.

Illustrative Matter.

Illustrations should accompany manuscript, on separate sheets. A good line drawing is often more valuable than a photograph. Shading, stippling, and other black-and-white devices may be used to give depth and variation to line drawings. Wash drawings must be reproduced by the more costly halftone process.

Figures and graphs. Copy for figures and graphs should always be drawn large enough to allow for at least one-

third reduction by the engraver. Copy should consist of carefully prepared line drawings in one colour only, drawn in India ink on plain white drawing paper or tracing cloth. Co-ordinate paper with lines in light blue (a colour which will not show in a photograph) may be used; but co-ordinates which are to appear in the finished graph must be drawn in India ink. If original figures may not be conveniently submitted with manuscript, duplicate rough sketches or photographic prints may be furnished to aid the editors in their decisions. Numbers and legends to be set up by the printer should be penciled in the margin, along with serial number or other identification of the drawing to correspond to list of captions. Scale should be shown on the figure if needed.

Photographs. Photographs should be chosen for clarity in portraying essential information. They should be printed for contrast, on glossy paper, and should be sent unmounted. Photographs submitted should be large enough to be reduced by the engraver by at least one-third. They should be identified with serial number written in soft pencil on the back to correspond with list or captions. Scale of photograph may often be shown by including in the picture a ruler or object of standard size.

Tables. Tabular matter should be kept to a minimum. Care should be taken to avoid any arrangement which unduly increases depth of a table, and column heads should be made as short as possible. Abbreviations may be used if necessary. Any superior or inferior figures or letters (e.g., to mark footnotes) should be clearly indicated. Tables should be titled and numbered. Each table should be typed on a separate page, and its position indicated on the manuscript.

Captions. Readily identifiable captions for figures, graphs, photographs, and other illustrative matter should be supplied.

Proofs and Reprints.

After notification of the Executive Committee's decision to include a paper in the Proceedings, the author will be permitted to submit alterations to the text of the paper, up to but not later than twenty-eight (28) days after the end of the Council Meeting. If substantial modification of a paper should be proposed by the editors, the revised MS will be transmitted to the author.

Proofs. Only galley proofs will be submitted to authors. They will be despatched in specially identified envelopes and authors are requested to make arrangements for proof-reading on their behalf in the event of their absence. No substantial changes of the text will be allowed, and wherever possible changes required in wording should be made in a way that will cause minimum of disturbance of type. The Executive Committee will accept the responsibility, as far as lies in its power, of ensuring that author's corrections are duly made and of preventing the introduction of new errors. The author may make suggestions as to lay-out, bearing in mind the format of the Proceedings.

Reprints. Fifty reprints of each paper will be provided free of cost; where there is multiple authorship, these must be shared between the authors. Authors may order additional reprints at the time of returning proofs; the approximate cost of such additional reprints will be stated on the galley-proof.